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ORIGINAL ARTICLES.

I.—A Note on the Geology of Socotra and Abd-el-Kuri.

By J. W. Gregory, D.Sc., F.G.S., of the British Museum (Natural History).

THE first account of the geology of Socotra we owe to Lieutenant J. R. Wellsted,[1] who compiled the Admiralty chart and map, and in 1835 described the island in a detailed memoir, in which he showed that it consists of a mass of granite capped by limestones. Nothing material was added to this description until 1883, when Professor Bonney published his account[2] of the extensive rock collection made by Professor J. B. Balfour during a six weeks' visit to the island in February and March, 1879. Professor Bonney's study of the rock specimens enables him to prove that Socotra consists of a block of Archean rocks covered in places by massive limestones, which, on the evidence of their foraminifera, Professor T. R. Jones suggested were probably of Miocene age. It was further shown that both the Archean series and the Cainozoic limestones are cut through by dykes of trachyte and basalt, associated with a series of rhyolitic lavas. Professor Balfour's expedition not only proved that the foundations of Socotra are built of old materials, but that the island is of considerable antiquity, as is indicated by its rich endemic flora.[3]

In 1880 Socotra was visited by Emil Riebeck, who collected some rock specimens containing the mineral which was described in 1888 by Sauer under the name of Riebeckite.[4] Further details regarding the Archean and volcanic rocks were given in the same year in a paper by Miss Raisin.[5]

[1] J. R. Wellsted, "Memoir on the Island of Socotra": Journ. Roy. Geogr. Soc., vol. v (1835), pp. 129–229, and map.

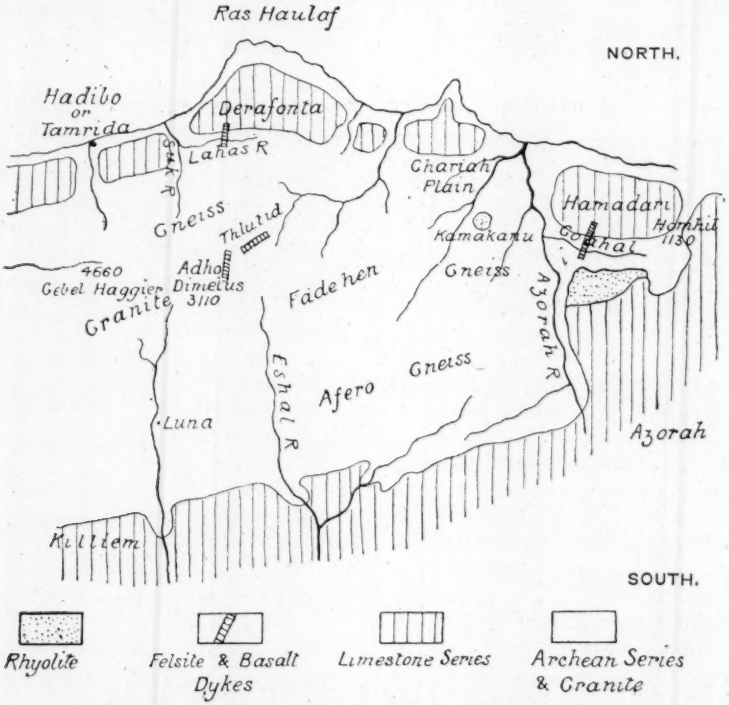
[2] T. G. Bonney, "On a Collection of Rock Specimens from the Island of Socotra": Phil. Trans., vol. 174 (1883), pp. 273–294, pls. vi and vii. Some preliminary remarks on the geology of the island were included in Professor Balfour's report, "On the Island of Socotra": Rep. Brit. Assoc., 1881, p. 486.

[3] According to Balfour ("Botany of Socotra": Trans. Roy. Soc. Edinb., vol. xxxi, 1888, p. lxxv) the island has been a land area since the Permo-Carboniferous, and "an island certainly from Tertiary times."

[4] Sauer, "Ueber Riebeckit, ein neues Glied der Hornblendegruppe": Zeit. deut. geol. Ges., vol. xl (1888), pp. 138–146.

[5] C. A. Raisin, "Rock Specimens from Socotra": Geol. Mag., Dec. III, Vol. V (1888), pp. 504–7.

During last winter Socotra and the neighbouring island of Abd-el-Kuri were visited by Dr. H. O. Forbes and Mr. Ogilvie Grant, who made a collection of rocks, upon which I have been asked to report. Dr. Forbes has given me an account of the mode of occurrence and distribution of the principal rocks. At about the same time both islands were visited by the Austrian South Arabian Expedition in the "Gottfried," and a note on their geology has been published by Dr. F. Kossmat, in which he remarks the occurrence of Cenomanian and Eocene limestones.[1]



GEOLOGICAL SKETCH MAP OF NORTH-CENTRAL SOCOTRA.

The present collection does not necessitate any modification in the geological history of Socotra, as deciphered by Professor Bonney from the materials available in 1883. But the collection adds to the knowledge of the distribution of the different rocks in the island.

1. SOCOTRA.

The rock collection from Socotra contains representatives of three groups of rocks—a basal Archean series, some massive limestones, and some comparatively recent volcanic rocks.

The largest part of the collection consists of Archean rocks and some associated granites. As a rule the gneiss is more granitoid

[1] F. Kossmat: Sitz. math. nat. Cl. k. Akad. Wiss. Wien, 1899, No. ix, pp. 73–82.

than the rock which forms the main mass of the East African Archean plateau; but a specimen from Thlutid, at the height of 900 feet, corresponds with the typical gneiss of the mainland. With the granitoid gneiss there is a coarse pink granite which forms the summit of Gebel Haggier, the highest peak in Socotra; it occurs also at Adho Dimellus, and at the height of 1500 feet at Fadehen.

The second group of the Archean series consists of dark-green amphibolite schists, of the type that forms such a conspicuous feature in the East African gneiss series. This rock was collected by Dr. Forbes in the Hadibo Plain near Tamrida.

The Archean rocks of Socotra therefore resemble those of the East African Nyika series, and the island is simply an outlier of the East African plateau.

Overlying the gneisses is a compact, massive limestone which has been sometimes rendered coarsely crystalline, probably by contact metamorphism. This limestone forms the extensive plateau at the eastern end of the island, and according to Dr. Forbes sections cut by the Goahal river show that the limestone there rests directly on the Archean series. South of the Goahal river the limestone forms a plateau, the southern end of which is continued westward round the southern flanks of the central highlands. From the Hamadari plateau a belt of limestone extends westward to beyond Tamrida; the rivers have cut through it, showing that it rests on the Archean series.

The collection gives no evidence as to the age of the limestones, but fortunately Herr Kossmat has obtained from it a number of mollusca and echinids, which enabled him to determine it as Eocene. Kossmat also records an underlying Cenomanian sandstone with *Janira quinquecostata*.

The last group of rocks represented in the collection is a series of recent volcanic rocks, of types already described from Socotra by Professor Bonney and Miss Raisin.

The volcanic rocks include rhyolites, quartz-felsites, and basalt. Most of the specimens are dyke rocks, but one lava is included in the collection. It is a rhyolite with well-marked fluxion structure and containing many angular fragments; it was collected on the edge of the plateau, south of the Goahal river. A similar rock has been described and figured by Professor Bonney[1] from Azorah, and according to Dr. Forbes the rounded hill in the Ghariah Plain near Kamakanu consists of the same rhyolite.

Quartz-felsites were collected from dykes intrusive in the Archean series at Homhil and Adho Dimellus. The felsites at both localities are intensely altered by decomposition; the abundant iron-ores have been altered to leucoxene, and the matrix is stained bright red. The only unaltered minerals are the large phenocrysts of quartz; and they are deeply corroded, as illustrated by Velain[2] from the quartz-trachytes of Aden, and by Miss Raisin[3] in a quartz-felsite from Socotra.

[1] Bonney: op. cit., p. 287, pl. vii, fig. 5.
[2] Ch. Velain: "Descript. géol. presqu'île d'Aden," 1878, p. 18, fig. 2.
[3] Raisin: op. cit., p. 505, fig. 1.

In one case the quartz shows a zonal arrangement of the inclusions, a feature unusual in volcanic quartz crystals; but the identification of the mineral was confirmed by the use of convergent polarized light. The felsite from Adho Dimellus has numerous, somewhat ill-defined spherulites; in that from Homhil some of the smaller patches of secondary quartz are traversed by faint lines like cleavages, suggesting that the quartz has been formed by the alteration of tridymite aggregates.

The last member of the rhyolite-felsite series is an altered, fine-grained trachyte from the Ghariah Plain. It is similar in character to the trachyte figured by Professor Bonney[1] from the Azorah district.

A dyke of a fairly fresh basalt was found by Dr. Forbes at Thlutid, on the north-west slope of the granite mass of Adho Dimellus.

The most interesting feature in the trachyte and felsite is that the rocks resemble those of the Aden volcanic series rather than those of the East African volcanic group. For opportunities of examining some of the Aden rocks I am indebted to Mr. G. T. Prior.

Hence Socotra appears to be an outlier of the Somali plateau, which has been involved in the movements which formed the Gulf of Aden, and has been the scene of the eruption of volcanic rocks of the Aden series.

2. Abd-el-Kuri.

West of Socotra is the small island of Abd-el-Kuri, where a larger rock collection was made by Messrs. Forbes and Grant. It was also visited by Dr. Kossmat, who has described it as composed of amphibolites, penetrated by a network of granites and camptonite dykes, and capped by a limestone which he suggests to be of Turonian age. The only previous geological account of the island known to me is by H. J. Carter,[2] who in his memoir on the geology of the south-east coast of Arabia described Abd-el-Kuri as composed of a mass of granite and diorite, capped by a limestone which reaches to the summit at the level of 1600 feet above the sea.

The collection from Abd-el-Kuri is composed mainly of rocks belonging to the Archean series. They include a series of amphibolite schists, a syenitic gneiss, some specimens of which have a considerable development of epidote, and a white gneiss with hornblende aggregations: the last rock is strikingly like one which is common in the Ulu Mountains of Ukambani in British East Africa. This series of foliated rocks is cut through by pegmatite dykes, which are almost as coarse in grain as those of Somaliland: in one specimen collected the muscovite occurs in crystals from two to three inches in diameter.

The Archean rocks are covered by limestones which occur at different levels from 40 feet above the sea to the summits of Gebel

[1] Bonney: op. cit., p. 287, pl. vii, fig. 6.

[2] "Geol. Papers on Western India," 1857, p. 620. On p. 621 of the same work Carter describes 'The Brothers,' the islets between Socotra and Abd-el-Kuri, as also formed of granite and diorite capped by limestone.

Saleh and Gebel Somali, the highest peaks in the island. The limestones appear to be very fossiliferous, and one specimen is crowded with shell fragments; but the only specimen generically determinable is a *Nerinæa* in a block of limestone collected by Dr. Forbes at the height of 700 feet. The limestone at that point is therefore no doubt Cretaceous.

On the lower parts of the island a reef limestone occurs up to a height of 40 feet above sea-level. As it contains well-preserved specimens of *Goniastræa retiformis*, it is no doubt of Pleistocene age.

II.—Notes on some Hardanger Lakes.

By Horace W. Monckton, F.L.S., F.G.S.

In many places in Western Norway we find a lake separated from a fjord by a mile or so of sand and gravel. Looking from the fjord, we see in such a case a series of step terraces, with possibly a high mound at the back, forming a dam at the end of the lake.

Several examples of this arrangement were mentioned by Amund Helland in a paper published by the Geological Society in 1877,[1] and he adopts the explanation suggested by S. A. Sexe,[2] that the dam at the end of the lake is a moraine formed when a glacier filled the space now occupied by the lake; in short, that it is the terminal moraine of a glacier which must have halted for some time at the point during the retreat of the ice, and consequently these mounds and terraces were formed at the close of or after the Glacial Period, for any advance of the ice beyond their site in the valleys would have carried them away to a greater or less extent.

During visits to Norway in 1896, 1898, and 1899, I have explored several of the valleys in which these moraines occur, and I think the following notes may be of interest.

I will first describe a side valley which branches off south from the great valley of the Hardanger Fjord, between 80 and 90 miles from the open sea. It is a deep channel carved out of gneiss, and the sides have in many places been scored and smoothed by ice, and these smoothed rock-sides pass behind all the deposits in the valley, showing that it is older than them all; in this it differs from many of our English valleys, that of the Thames for instance, where we believe that the valley is more recent than the drift around it and that the gravels in the valley mark stages in its excavation.

The mouth of the branch of the Hardanger Fjord valley of which I am speaking is at Vik i Eidfjord, and it has been filled up with gravel, sand, etc., almost to the edge of the main valley, so that there is but a small bay or indent in the fjord at its mouth.

From the fjord one sees a series of step terraces rising one above the other, the highest being on the east side with a flat top and of considerable extent.

If we follow the river up from its mouth we find that it has cut a channel through all the terraces, which look like great railway

[1] Quart. Journ. Geol. Soc., vol. xxxiii, p. 142.

[2] "Mærker eften en Iistid"; 4to; Christiania, 1866.

embankments on either side, and rather more than a mile from the fjord we reach a lake, the Eidfjord Vand. Its depth is 246 feet, the surface is 56 feet above the sea, and the bottom is therefore 190 feet below the surface of the fjord. These figures are from a paper by Amund Helland;[1] in other cases I have done my best to obtain accurate figures, but have sometimes had to rely on my pocket aneroid.

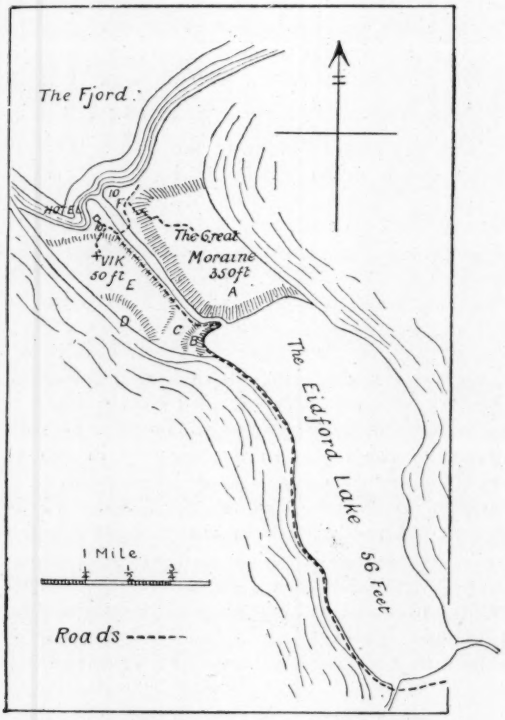


FIG. 1.—SKETCH MAP OF VIK I EIDFJORD.

A, the great moraine on the east of the river; B, the portion of the great moraine on the west of the river; C, space of bare rock to seaward of the great moraine; D, the shelf, probably a fragment of the great moraine; E, the terrace upon which Vik i Eidfjord Church stands; F, the 10 feet terrace upon which the hotels stand.

On looking at the map (Fig. 1) it is clear that almost the whole of the material of which all these terraces are formed must have come down the valley and over the lake, the length of which is $2\frac{1}{2}$ miles, and it must consequently have been brought whilst the ice had possession of the lake.

The highest terrace is on the east side of the valley, and if we mount to its top we find ourselves on a large plain, say one mile

[1] "Dybderne i nogle indsjöer," etc.: Norges. Geol. Undersögel, 1894, p. 93.

long and half a mile wide, with a slight slope to the sea. It extends from the lake nearly to the fjord, and is bounded on the east by the steep rocky side of the valley and on the west by a deep channel cut by the river which flows from the lake to the fjord. On the top there is a village and fields.

The flat top shows that the sand, gravel, and stones of which this vast mound consists must have been spread out under water, no doubt the water of the sea. Its height is about 350 feet above the sea, so that at the time of its deposition the land must have stood at least 350 feet lower than now.

Fig. 2.—The Eidfjord Vand, Vik i Eidfjord, Hardanger.

The moraine on the west side of the river is not so large. Its top is more rounded and not quite so high. Its highest point is near the west side of the valley, and from it I could see the houses on the great moraine opposite, so that the difference in level is not large. The north end of the lake, with the great moraine, is shown in the photograph, Fig. 2, which was taken from the road on the west of the lake. On the whole, it seems to me probable that the bank originally stretched across the valley at about the same height, and that the present difference in level is due to the erosion effected by waters flowing down the valley. At what period in this erosive process the ice left the site of the lake is not quite clear, but that it must have been at a fairly early period is shown by certain step terraces at the southern or upper end of the lake and by old shore-lines on the great moraine itself.

There are two fairly well-marked shore-lines on the lake face of the moraine, one about 100 feet above the surface and the other rather lower. These no doubt mark stages in the deepening of the outlet by which the river flows to the sea: probably the deepening of the outlet bore some relation to the rise of the land. On the west of the outlet there is a working for gravel on the inner face of the moraine, and it shows ordinary moraine stuff—sand, gravel, and stones of all sizes, mixed loosely together.

There is a rough stratification parallel to the face of the bank, as though material had been carried off the top and rolled down the face of the moraine towards the lake, and this makes me suspect that the ice had left the face of the moraine whilst it was still submerged beneath the sea. At the top of the pit there is a little blue stratified clay. It is about 50 feet above the lake, and I saw in 1899 a small section in a similar blue clay by the roadside near the western end of the moraine, about 15 feet above the lake. The section was about $2\frac{1}{2}$ feet deep, and exposed stiff blue clay well stratified with a layer or two of ferruginous deposit. These clay deposits show that the level of the lake was lowered very gradually.

Passing now to the south end of the lake, we find an alluvial flat of considerable extent, on which the village of Sæbö stands, and above the flat are some step terraces up to a level of perhaps 200 feet. These terraces clearly cannot have been formed when the glacier extended down the valley beyond them, and they are flat and have obviously been deposited under water—the water of the lake. They therefore belong to the period when the ice had left the lake and when the water of the lake stood at least 144 feet higher than now; in other words, before the river had cut down its outlet to a depth of more than 207 feet below the top of the highest terrace. Taking this together with the evidence furnished at the moraine end of the lake, I am led to suspect that the glacier left the lake during an early part of this cutting-out process.

Two valleys meet at Sæbö, and in both we find moraines and terraces. The western valley is Hjalmodal, and near its mouth there is a moraine of great blocks reaching a height of over 300 feet above the sea, and also a fairly flat-topped moraine at a rather lower level. The eastern valley eventually leads up to the celebrated Vöringsfos. At the lower end above Sæbö a knob of rock stands out, or rather did stand out, in the middle of the valley, and the space between it and the valley wall is filled in with moraine stuff to a height of some 200 feet above the river. Small sections show that this is in part stratified sand. The River Bjoreia flows round the other side of the knob, and above the river are small terraces.

A little further up the valley a sandy flat seems to mark the site of a small lake; terraces occur on both sides, and probably once formed a barrier across the valley when the glacier occupied it as far down as this point. The river has now removed much of this barrier, and the lake is dry.

I now return to Vik i Eidfjord and the step terraces between the fjord and the great moraines. They are confined almost to the west

side of the river, of which the part between the lake and the fjord is named the River Eieo, almost all the east side being occupied by the high moraine. The river and terraces are seen in the photograph, Fig. 3. The most extensive terrace is the flat upon which the church and village of Vik stand. It is about 50 feet above the fjord and rises inland. Below it there is a smaller flat, say 10 feet above the fjord, on which the Hotel Vöringsfos stands, and still lower there is a fair extent of flat at the present level of the river. Each of these flats must mark pauses in the elevation of the land, and, as I have suggested above, the river probably cut its channel through the moraine deeper in proportion as the land rose.

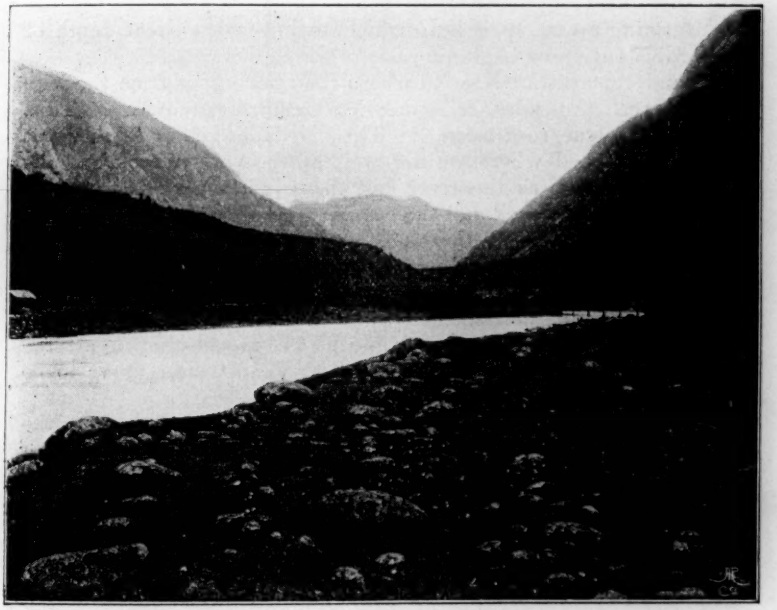


Fig. 3.—View from the Mouth of the River Eieo, Vik i Eidfjord.

As I have shown that the ice left the lake at any rate before the channel had been excavated to anything like its present depth, and as all the material of which these terraces are formed must have been brought across the lake at the same time as that of which the highest terrace is formed, I am inclined to think that originally the highest terrace filled the whole valley from side to side and from the lake to the fjord, and that the step terraces are not formed by subsequent deposition but have been carved out of it by river erosion.

My reasons for this conclusion are as follows:—

At the seaward side of the moraine on the west of the river there is a space where bare rock is exposed practically from the river to the side of the valley (Fig. 1, C), but nearer the fjord there is

a prominent ledge or shelf (Fig. 1, D) of moraine stuff with a flat top nearly as high as the corresponding part of the highest terrace on the other side of the valley. I think this must be a fragment of the highest terrace, and if so shows that it extended a long way down the west side of the valley.

Again, close to Vik Church there is an oblong mound running north and south; the top is flat and 67 yards long, and its height perhaps 40 feet. My attention was drawn to it by Herr Næsheim, the proprietor of the Hotel Vöringsfos, and at first I was at a loss to account for it. I now think it is a fragment of a higher terrace, which has been left by the river when it cut down to the church flat.

At the present time, too, the river is carving out a terrace at sea-level and throwing the material removed from its banks into the fjord, forming a vast spoil heap which, owing to the great depth of the fjord, is only now beginning to project slightly.

Helland remarks: "Near to where the river issues from the lake the solid rock protrudes, being here covered with groovings. Thus the lake is a true rock-basin."[1] This no doubt refers to the spot already mentioned where, on the west of the valley, rock extends nearly as far down as the river, but there is a space of about half a mile between this rock and the eastern face of the valley, which is covered by moraine. I therefore see nothing to show that the bottom of the old valley is not buried under this moraine, and would observe that the course taken by the overflow from the lake over the top of the moraine could have no reference to the shape of the bottom of the rock valley beneath. I suspect that if all the moraine stuff were removed the Eidfjord Vand would prove to be an arm of the Hardanger Fjord.

Some thirteen miles west of Vik a long arm runs south from the Hardanger. It is the Sör Fjord, and at its head we find many of the features described above repeated. There are again step terraces, on one of which stands Odda, and there is a vast moraine forming a dam to a lake—the Sandven Vand. The moraine attains a height of 446 feet above sea-level. The top is not flat, but forms a mound, its shape being, as Helland suggests, probably due to the fact that its top stood above the sea-level at the time of its deposition. Below there is a large flat terrace at a level of about 308 feet above the fjord.

The step of the terrace on which the school at Odda stands has a slight slope away from the fjord, the result of the manner in which the river has carved it out; and in cutting out the lowest terrace, the river has left a bank projecting from the next step between the lowest terrace and the fjord, which, until I realized that these terraces were cut out, somewhat puzzled me.

We will now cross to the north of the Hardanger Fjord and glance at the Graven Fjord, with its lake, the Graven Vand. That lake is a mile from the fjord. Its level is 95 feet above the sea and it is 282 feet deep. At the head of the fjord there is a large flat with a long slope under water, which is in process of extension by the present action of the river. This flat extends for some distance

[1] Loc. cit., p. 166.

inland, and on the east reaches the side of the valley. On the west there are terraces at varying levels, and in one of them there is an unusually good section, of which I took the photograph, Fig. 4.

The height of the section is about 30 feet. It shows typical moraine stuff very well stratified. In the lower part are some fair-sized boulders in a bed of sand, and they stand out and produce a sort of earth-pillar structure. I could not find a trace of shells. The bottom of the section is about 10 feet above the fjord. Between the fjord and the lake are mounds and terraces, and near the end of the lake there is a flat-topped terrace which may once have crossed the valley, but now the river flows with a fairly even slope from the lake to the fjord.

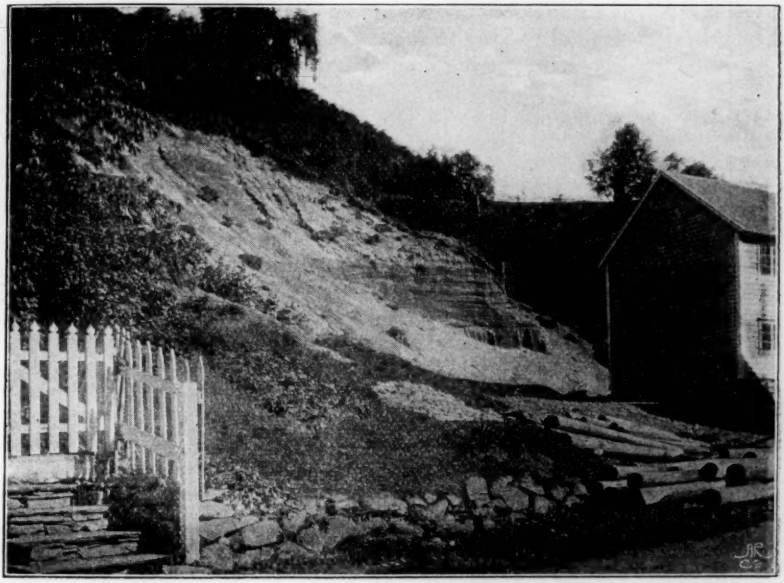


Fig. 4.—Section in a Sand-pit near the Landing-place, Eide, Graven Fjord, Hardanger.

Above the Graven Vand there are extensive terraces, one or two of which, I believe, are old moraines of which the top has been flattened artificially. There are others which mark old water-levels, and in one by the roadside at a stone 20 kilometres from Voss there is a good section showing well-stratified sand with a few stones. There is a fairly extensive flat at a level of 30 feet above the lake and a smaller terrace 10 feet higher. In it I saw the following section:—

Section in Flat-topped Terrace, Seim i Graven.

1. Earth, 9 inches.
2. Stones of various sizes, with little or no sign of stratification.
3. Coarse sand, well stratified and showing current bedding; 4½ feet seen.

I imagine that these flats and terraces mark former levels of the fjord. There is no evidence that either the Sandven Vand or Graven Vand are rock basins, but in conclusion I will say a few words about a lake which I am inclined to think is a rock basin, though I could not prove this for certain without boring. I refer to the lake at Noreimsund on the north side of the Hardanger Fjord.

The outlet of the lake reminds one of the outlet of Loch Etive, near Oban, but it is on a much smaller scale and is the best example of its kind I have seen. The water flows over a rock-lip, the whole of which from shore to shore is perfectly clear. At high-tide the lake becomes, in fact, the end of the fjord, whereas at low-tide a stream pours over the rock and forms a small cataract. There is one place, about a hundred yards west of the outlet, where rock does not show at the surface of the ground, and where there may possibly be a buried channel passing to the fjord behind the village. In any case the locality is interesting and well worth a visit.

III.—A Contribution to the Discussion on Rock-weathering and Serpentinization.

By T. H. Holland, Officiating Superintendent, Geological Survey of India.

BY correlating the head and the tail of Professor G. P. Merrill's "Discussion on the use of the terms Rock-weathering, Serpentinization, and Hydrometamorphism,"[1] I infer a direct invitation to confer with him on the questions raised by me at the Bristol meeting of the British Association.[2]

At the outset it should be explained that, though not so apparent from the published abstract, reference to the full text of my paper as read shows that Professor Merrill and I have on many points independently arrived at similar conclusions.

In his "Treatise on Rocks and Rock-weathering," Professor Merrill called attention to the not unfrequent omission in geological literature of a precise distinction between the work of subaërial agents and the deep-seated forms of hydrometamorphism and alteration. But although he included "epidote, chlorite, sericite, leucoxene, kaolin (?), pyrite, and various zeolitic compounds" in the latter category, he made no mention of serpentine. Professor Merrill says that the distinction drawn by him in 1897 between weathering and the more deep-seated alteration of rocks is essentially that made by Roth between *Verwitterung* and *complicirte Verwitterung*.[3] He also now says that whilst Roth in 1869 spoke of serpentine and zeolites as products of weathering (*Verwitterung*), he so far changed his views or mode of expressing them in his latest work (1893) as to call the deep-seated process *complicirte Verwitterung* in distinction from the purely superficial *Verwitterung* due to atmospheric action.

[1] Geol. Mag., August, 1899, pp. 354–8.

[2] "The Comparative Actions of Subaërial and Submarine Agents in Rock Decomposition": Rep. Brit. Assoc., 1898, p. 868; Geol. Mag., January, 1899, p. 30.

[3] "Rocks and Rock-weathering," pp. 161 and 174 (footnote).

These are by no means the impressions I have gathered from Roth's writings, in which I can find no change of views between 1869 and 1893, and nowhere any consolation either for my views of the origin of serpentine or of Professor Merrill's modification of them. Roth[1] distinguished *einfache Verwitterung* — the simple chemical reactions produced in rocks by the action of atmospheric air, water, and the contained gases — from *complicirte Verwitterung*, which is due to the complex reactions of solutions formed by the first process. By the use of the term *complicirte Verwitterung* Roth merely referred to the complex nature of the chemical reactions, and never suggested that the water of these solutions was other than of immediate superficial origin. The action of superheated water, steam and other vapours from deep-seated sources, Roth distinguished under quite a different name as *Zersetzung*, which is unfortunately the term *decomposition* by which Professor Merrill proposes to distinguish true weathering from the more deep-seated *alteration* and *hydrometamorphism*.[2]

Moreover, although it is true, as Professor Merrill says, that Roth in his "Ueber den Serpentin" described the processes and results incidental to the *Verwitterung* of the serpentine quite independently of those incidental to its first production, he did not recognize any essential difference between them; but, on the contrary, says expressly, "die Verwitterung des Olivins zu Serpentin nur ein Stadium des Prozesses bezeichnet, der Serpentin unterliegt seinerseits einer weiteren Verwitterung."[3] Roth evidently considered serpentinization to be induced by meteoric waters, and referred definitely to the oxidation as a phase of the process. Both in his first volume, which appeared in 1879 (p. 113), and in the last volume of his "Chemische Geologie" (1893, p. 422), he refers to the serpentinization of olivine under the heading "Einfache Verwitterung des Olivins." On this account, coupled with the acquiescence by silence or applause on the part of English writers, I brought the new facts obtained in India to the notice of the British Association, and concluded therefrom that atmospheric agents had practically nothing to do with the formation of serpentine rock. On the same occasion, by comparing the geological history of the Madras Presidency, where fresh olivine rocks occur abundantly, with that of the Andaman Islands, Kashmir, and Baluchistan, where our serpentines are found, it was suggested, as a basis for discussion, that submergence below sea-level favours the formation of serpentine.

[1] Allgemeine und Chem. Geol., vol. i (1879), pp. 1, 2, 43, 47, and 159.

[2] As results of *complicirte Verwitterung* Roth included the zeolites and many of the minerals considered by Professor Merrill to be due to agents of deep-seated origin. I agree with Professor Merrill's list (serpentine not being on it), but I see no support for our views in the writings of Roth. His later use of the expression agrees exactly with the statements made in earlier papers, where the verb is not given an adjectival form, as in "complicirt sich die Verwitterung des Felsitporphyrs durch Zufuhr von Kalk und Eisen aus nahe gelegenen Partien, so entstehen 'Epidosite' Gesteine' (Abhand. der Akad. der Wiss., Berlin, 1869, ii, 133).

[3] Abhand. der Akad. der Wiss., Berlin, 1869, ii, 345 and 346.

Professor Merrill has now advanced further evidence in support of my first point by showing that there are essential chemical differences between serpentine and the weathered products of magnesian rocks.[1] Although, however, we are agreed, Professor Merrill and I, that serpentine, as one instance of a secondary hydrous mineral, has been wrongly ascribed to weathering, we find ourselves at variance when we pass from destructive criticism to the creation of a more satisfactory substitute for the old ideas.

As the presentation of objections to an opponent is generally an easier problem than proving one's own case, I will commence with a criticism of Professor Merrill's theory. According to his view, "serpentinization is a deep-seated process[2] due to waters or vapours coming from considerable depths, and it may be even constituents of the magmas at the time of their intrusion." "The almost complete absence of oxidization products in fresh serpentine is," he says, "indicative of this."[3]

This last clause, given as a reason for the conclusions indicated in the previous part of the same paragraph, is the one which I would first of all criticize, and against which I will produce, besides the statements of Roth, the testimony of a very reliable authority to show that oxidation is a constant, and presumably essential, phase in the formation of serpentine from olivine :—

"The serpentinous alteration [of olivine] takes place along the irregular curvilinear lines of fracture, and under favourable conditions continues until the transformation is complete. . . . . The iron, which existed as protoxide, is further oxidized, and crystallizes out along lines of fracture as magnetite or hematite, or in the hydrous sesquioxide form known as limonite."

"In this process of hydration the combined iron becomes converted into the sesquioxide form."

"The mineral olivine, an anhydrous ferruginous silicate of magnesia, passes over into serpentine by a simple process of hydration, and a more or less complete change of its combined iron from the ferrous to the ferric state."

So we learn from the fascinating "Treatise on Rocks and Rock-weathering."[4] And in this matter its author is in perfect agreement with other earlier authorities. The limited amount of oxidation may be claimed to be as consistent with the submarine as the subterranean theory, but as it is not part of the evidence on which I base the former it may be left out of the present argument.

"The action of waters or vapours coming from considerable depths" has often been referred to by earlier writers as the cause of

[1] That serpentine loses water by exposure to the weather is not in itself, however, a proof that the previous hydration of the olivine was not effected by atmospheric water. Laterite, which is unquestionably a product of true, though peculiar, weathering, loses water on exposure even to a humid atmosphere.

[2] W. Lindgren in 1896 also referred to serpentinization as a deep-seated process, which, he said, should not be referred to weathering: 17th Annual Report, U.S. Geol. Surv., pt. ii (1895–6), p. 92.

[3] Geol. Mag., August, 1899, p. 356.

[4] pp. 24, 25, 97, 158, and 159.

certain alterations amongst the secondary minerals mentioned by Professor Merrill.[1] The formation of zeolites by the action of thermal springs in brickwork was, everybody knows, considered by Daubrée to be a sufficient explanation of the origin of the amygdales in volcanic rocks, and the same author suggested further that palagonite and serpentine were formed in a similar way.[2] Of the other secondary minerals, without going into the extensive literature which exists, it will be necessary only to recall the processes by which the formation of kaolin, epidote, chlorite, biotite, and magnetite has been traced out in detail by Professor Judd[3] in the propylites of the western isles of Scotland, as the result of solfataric action on previously fresh rocks of the andesitic and dioritic types, which are the oldest of the Tertiary eruptives in that area. Professor Judd carefully emphasizes a distinction between the widely-spread effects of solfataric action and the somewhat similar, but purely local, effects of contact-metamorphism.

The other point raised by Professor Merrill, namely, the behaviour of the water and other vapours included in the magma, has not, I admit, been so generally recognized, and for that reason I have recently taken advantage of more than one opportunity of bringing the importance of this matter into prominence. In 1897 it was pointed out that the water excluded from the mother-liquor by the separation of anhydrous minerals from a basic aquo-igneous magma may attack the susceptible ferromagnesian silicates previously crystallized from the same magma, with the formation of secondary biotite and magnetite.[4] There are reasons for supposing that a similar explanation applies to the zeolites of the Deccan Trap in localities distant from any volcanic vent.[5]

But the idea, nevertheless, is not an original one; for although J. D. Dana[6] held in 1845 that amygdales were formed by the infiltration of water, probably sea-water, he expressed a modification of his views in 1880, stating "that the moisture which made the amygdaloidal cavities was the moisture which altered the pyroxene or other minerals of the rock to chlorite, and made the zeolites and

[1] "Rocks and Rock-weathering," pp. 161 and 174 (footnote).

[2] Quart. Journ. Geol. Soc., vol. xxxiv (1878), p. 82.

[3] Quart. Journ. Geol. Soc., vol. xlvi (1890), pp. 341–382.

[4] "On Augite-diorites with Micropegmatite in Southern India": Quart. Journ. Geol. Soc., vol. liii (1897), p. 405.

[5] In a memoir on the Salem rocks, now in the press, evidence is given which indicates an origin similar to this for the magnesite which is so constantly found veining the peridotite masses in South India. Most, if not all, these peridotite eruptions are accompanied by masses of white quartz containing liquid carbonic acid. The association of these two rocks is too constant to be fortuitous, and is suggestive of a genetic relationship, the quartz being more probably the siliceous end-product of the eruption in each instance, and in the absence of alumina and alkalies consolidates as simple quartz instead of forming alumino-alkaline silicates. That being so, the large quantities of carbonic acid under pressure might attack the olivine, with formation of magnesite and separation of chalcedonic silica. The water associated with the carbonic acid accounts for the small quantities of picrolite always found in these peridotites, which, however, never show a general serpentinization of the mass.

[6] "Origin of the constituent and adventitious Minerals of Trap and the allied Rocks": Amer. Journ. Sci., vol. xlix (1845), pp. 49–64.

quartz chiefly out of its felspars."[1] Scrope, even as far back as 1825, suggested that these secondary minerals in trap rocks are the results of vapours accompanying volcanic eruptions, though he admitted that additional material might subsequently be obtained by the infiltration of solutions from overlying rocks, especially "calcareous strata."[2] In 1897 Sir A. Geikie pointed out that though it is a common belief that the filling in of the steam cavities has taken place long subsequent to the volcanic period by the slow percolation of meteoric water through the rock, he believed that at least in some cases, if not all, the conversion of the vesicular lavas into amygdaloids was effected during the volcanic period, the amygdales themselves sharing in the general metamorphism induced by later eruptions.[3]

Although different opinions are recorded concerning the origin of certain of these secondary minerals, there is a fair agreement in literature with regard to the *possible* origin of secondary chlorite, biotite, epidote, magnetite, and the amygdaloidal bodies in basalts by the action of subterranean vapours, both during and subsequent to the consolidation of the rocks in which they occur. Although, moreover, more than one mode of origin has been granted for certain of these minerals, I cannot subscribe to Professor Merrill's verdict that "geologists and petrologists as a rule have been extremely careless in their use of such terms as *alteration*, *decomposition*, and *weathering*." Roth gave a wider meaning to weathering than most, but before, during, and since his time many of the minerals regarded by him as products of weathering have been referred to deep-seated agencies. Kaolin and, with evident misgivings, serpentine have, however, until recently been generally looked upon as the work of meteoric waters. After what has been written above and published in other papers, it would be difficult to prove that I entertain any predetermined bias against the action of deep-seated agencies. On the contrary, knowing what has been done in connection with epidote, chlorite, and the other secondary hydrous minerals just referred to, the first step to take, after abandoning the weathering theory, would most naturally be an examination of the possibility of serpentinization by deep-seated agencies.

The very facts, however, which indicate in India the insufficiency of weathering to account for serpentine masses, point to quite a different conclusion; and until these facts have been shown to be purely local and exceptional, or until they are proved to be necessary accompaniments of some more far-reaching cause, the submarine theory remains as the first and simplest inductive inference. Briefly the facts are these:—At different points in the old crystalline land area in the Madras Presidency, Mysore, and Coorg, we know of more than a dozen occurrences of peridotites, chiefly dunites, but not a single mass of serpentine. In the Andaman Islands, Burma, Kashmír, Baluchistan, and near the North-West frontier—areas which

[1] Amer. Journ. Sci., ser. III, vol. xx (1880), pp. 331–2.
[2] "Considerations on Volcanoes," 1825, pp. 126–7.
[3] "Ancient Volcanoes of Great Britain," 1897, vol. i, pp. 16, 17; vol. ii, p. 189.

have been covered by Tertiary marine sediments—we know of about the same number of peridotite occurrences, which are all highly serpentinized. Fresh olivine is as scarce in the areas which have been submerged as serpentine is in the old crystalline block of Peninsular India, which has suffered uninterrupted subaërial denudation since at least Lower Palæozoic times. In the latter area it is not merely the dunites which have escaped hydration; the olivines of the basic dyke-rocks are equally fresh. If serpentinization is due, as Professor Merrill suggests, to waters or vapours coming from considerable depths, it is difficult to see why these rocks, erupted at different times and in well-separated localities in Peninsular India, should universally escape, whilst in the other areas mentioned, also widely separated by great distances, serpentinization should be so constant. With evidences of the action of deep-seated vapours in other ways in Peninsular India, the value of this point becomes accentuated. Besides olivine, other minerals, notably nepheline, are remarkably free of hydration in the Madras Presidency.

It was pointed out at Bristol that whilst fresh peridotites occur in a moist warm climate exposed to heavy rainfall, serpentines are found in the dry deserts of Baluchistan, and Professor Merrill has now produced similar evidence from America to show that the distribution of serpentine and of unaltered olivine-rock does not coincide with any general difference of climate. On the other hand, the areas containing serpentine have been submerged below the sea, whilst those in which fresh peridotites occur, so far as we know, never have been. The first inference is obvious, and the next duty is to discover if these circumstances in India are merely local accidents or in general agreement with the evidence obtained in other parts of the world. For this we must await the testimony of geologists who possess the necessary local knowledge.

By his reference to the fresh condition of the olivine in the Corundum areas of western North Carolina, Professor Merrill cites a case which appears to be in agreement with our observations in India. The crystalline belt which runs N.E.–S.W. through North Carolina is one of the few persistent sturdy old blocks of crystalline rocks which have been unaffected by late earth movements.[1] It apparently formed the south-eastern boundary of the old Palæozoic seas, and suffered a marine trespass only on its eastern borders during the Mesozoic and Tertiary times.[2] The distribution of the marine sediments and the principal directions of folding indicate that this crystalline 'Scholle,' to quote Suess' terminology, presents to the Appalachians a relation similar to that holding between our Peninsular 'Vorland' and the Himalayas. Here we have the negative side of the argument — in an area not known to be

[1] This belt has been the only serious rival with which Peninsular India has had to compete in the mica market, and the preservation of large sheets of delicate muscovite in coarse-grained pegmatite is generally a safe index of geological stability and quiescence.

[2] See Dana's "Manual of Geology," 4th ed. (1895), pp. 412, 443, 536, 633, 735, 813, and 881.

submerged since the eruption of the peridotites no general serpentinization has occurred.

But the area mentioned by Professor Merrill offers positive evidence also in agreement with the facts detailed for India:—The peridotites of western North Carolina lie in a chain of such eruptions whose outcrops occur at irregular, but frequent intervals along a narrow belt, stretching from Tallapoosa County in eastern Central Alabama, on the south-west, to Trenton, New Jersey, on the north-east, whilst fewer outcrops are recorded further northwards in the states of Vermont, New York, Connecticut, Massachusetts, New Hampshire, and Maine. In a paper on the Chromite of North Carolina, Dr. J. H. Pratt,[1] referring to this belt of peridotites, says: "In North Carolina and in the more southern portions of this belt the prevailing rock is dunite, while in the northern portion the secondary rocks, serpentine and talc, are prominent." Now, it is in the region of North Carolina that the crystalline hiatus is widest, whilst as the belt is followed in the north-east direction, the Triassic, Cretaceous, and Tertiary sediments are seen to encroach on the crystalline rocks, and to converge to the old Palæozoic boundary of the Appalachians, until, in Maryland and New Jersey, there is fair evidence to show that the crystalline rocks have been submerged more than once since the commencement of Triassic times.[2]

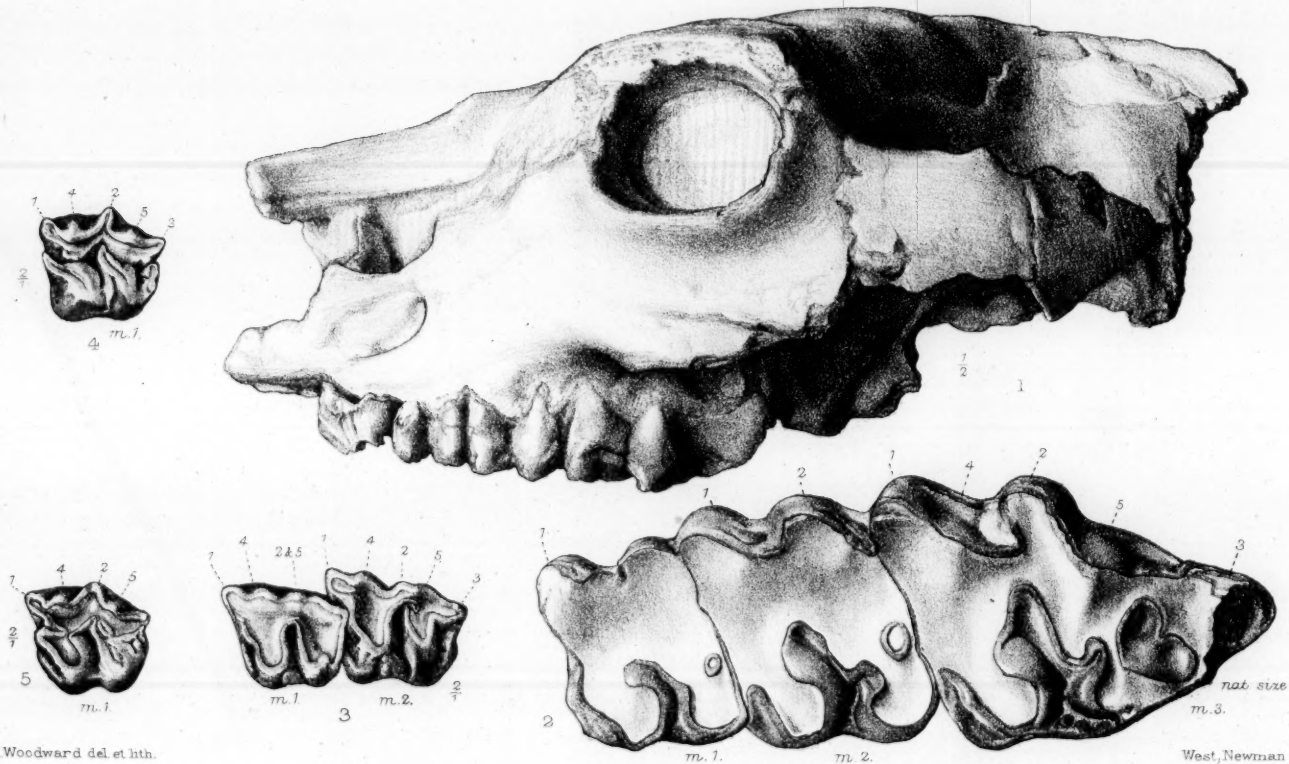
As many of these peridotite intrusions are found in contact with crystalline rocks only, their precise geological age is not known. But this and the exact value of such evidence can be discussed with profit only by the geologists possessing the necessary local knowledge. This opportunity might be taken to subpœna the Scandinavian and Canadian geologists, who are familiar with old crystalline land areas. One knows through Brögger[3] of the remarkably fresh olivine-rock of Söndmöre in Norway, which is not apparently near any marine sediments, though suspiciously near the coast. The ophicalcites and serpentines of the old schists would naturally be excluded from this discussion, as they would involve questions of origin far more complicated than that of simple serpentinization. Still, even they are suspiciously associated with limestones.

Old serpentines are known in the Lake of the Woods and Rainy Lake areas of Canada to be older than the folding of the Keewatins (Lawson); with the Cambrian and Cambro-Silurian of the Eastern Townships of Quebec (Ells); and with altered volcanic rocks in the lower part of the Carboniferous of the Kamloops region (Dawson). But I can recall no instance of a distinctly eruptive peridotite in the portions of the old Canadian crystalline protaxis which are not covered by marine sediments. The Canadian geologists will be able to tell us whether such exist, and to what degree they have been altered. The crystalline rocks of Canada have also been cut by basic dykes, and it would be interesting to know if the olivine

[1] Trans. Amer. Inst. Mining Engineers, Feb., 1899; see also literature therein quoted.

[2] See McGee's Geological Map of the United States, 1884.

[3] Neues Jahrb. f. Min., 1880, ii, pp. 187–192.



G.M. Woodward del. et lith.

West, Newman imp.

Pliohyrax graecus (*Gaudry.*) Upper Miocene Samos.

crystals which occur in some of these are slightly or extensively serpentinized, and whether also the recently discovered nepheline-syenites of Ontario, which are old enough to be crushed and foliated, contain fresh or altered nepheline.

"Just what would be the effect of prolonged submergence in sea-water on a mass of olivine rock," Professor Merrill is not prepared to say. Neither am I. But I see no flagrant theoretical objection to serpentinization under such conditions. On the contrary, it is theoretically to be expected that sea-water, acting under high pressure, would permeate rocks to greater distances,[1] and, being charged with carbonic acid as well as salts of lime, magnesia, and the alkalies, would form a more destructive reagent than rain-water when in contact with unstable silicates.

It is easy to foresee many difficulties which must be met should the submarine theory attain a maturity that warrants deductive tests. At present it has not reached that stage; for although the evidences, both positive and negative, from India indicate that a submarine existence has formed part of the history of every mass of serpentine, it will require the testimony of other areas to show that such submarine conditions are *essential* for serpentinization on an extensive scale.

In conclusion, it should be stated that Professor Merrill's paper has drawn me into this discussion earlier than was anticipated. Although the question has been under consideration for some years, the facts, so far, at my disposal warrant no further deductions than those tentatively offered for discussion at the meeting of the British Association. Keeping in view the fact that a mineral may be produced by more than one of the ways into which we classify the processes going on in Nature, recent observations indicate a fairly definite classification of the *usual* conditions under which secondary hydrous minerals are produced. Until these are established with more certainty, however, the formulation and definition of precise general terms might profitably be replaced by the accumulation of details concerning the paragenesis of each mineral.

IV. — The Hyracoid *Pliohyrax græcus* (Gaudry) from the Upper Miocene of Samos and Pikermi.

By C. I. Forsyth Major, M.D., F.Z.S.

(PLATE XXIV.)

AMONGST the hosts of Antelopes, Rhinoceroses, Hipparions, etc., which form the bulk of the Pikermi fauna described in Gaudry's classical "Animaux Fossiles et Géologie de l'Attique," the mandible of *Leptodon græcus*,[2] with lower molars recalling the Palæotheres and Paloplotheres, seemed to stand out, as it were, as an anachronism. It has always appeared to me, as it may also have to others, that the occurrence of such a type in the above company (with which

[1] Cf. J. D. Dana, Amer. Journ. Sci., vol. xlix (1845), pp. 57 and 58.

[2] A. Gaudry: "Animaux Fossiles et Géologie de l'Attique," 1862, p. 215, pl. xxxiv, figs. 1, 2.

Orycteropus and the Ostrich are also associated, in the contemporary beds of Samos) might be accounted for in a satisfactory manner, if *Leptodon* could be shown to be related to the Hyraces. Against such a relationship is opposed the large heel of the *Leptodon's* last molar; so that an affinity with *Titanotherium*, as suggested by Schlosser and Von Zittel, seemed to be more probable.

The skull in the Geological Department of the British Museum (No. M 5,419), briefly noticed by me in last month's GEOLOGICAL MAGAZINE (p. 507), was received from a dealer, labelled *Rhinoceros pachygnathus*, Wagn., and determined by me as *Leptodon*, for the reasons stated in my notice.

The skull is represented on Pl. XXIV, Fig. 1, of half natural size, left side view. The right side is damaged, and the anterior extremity, as seen from the figure, is wanting. The outline of the posterior part is misleading, as it seems to represent the contour of the occiput; this is due to the objectionable practice of shaping the matrix where the bone is absent, so as to make the specimen appear more perfect; the fossil was received in this state. What appears as the postero-inferior angle of the skull is the post-glenoid process. On the upper side of the skull the posterior part of the frontals and the upper parts of the parietals are missing, but the matrix beneath is preserved almost intact, so as to compensate partly for the missing bone. Temporal crests are thus seen to have been present, and these, starting from the posterior margin of the orbits, and converging backward, unite to form a sagittal crest, at a point situated approximately above the anterior border of the glenoid articulation.

The orbits are comparatively small, closed behind, situated high up and far backward (above m. 3).

The zygomata are very high throughout, short and strongly arched; their shortness backward from the orbit is of course in relation with the latter's posterior position.

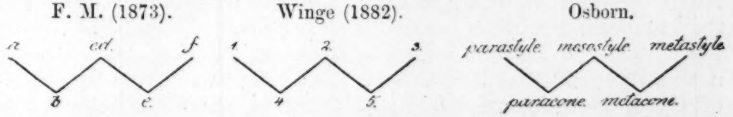
The infraorbital foramina are situated far backward, their posterior margin corresponding to the anterior part of m. 1. The bony palate is prolonged posteriorly beyond the molar series, so that the anterior border of the *choanæ* is situated about 25 mm. behind a line uniting the posterior ends of the two m. 3.

The true molars, which are considerably worn, present the following characteristic features:—

First of all the great elongation of m. 3, due to an additional third lobe, a sort of posterior heel. A common feature of the three true molars is the strong development of the outer cusps, numbered 1 and 2. The molars also appear to be less lophodont than we shall find to be the case in recent Hyracidæ; although much worn, they show traces of two cusps on the inner side. The conformation of the external parts of m. 1 and m. 2, showing only two protuberances or cusps, separated by a fold, is at first somewhat puzzling, and necessitates my entering into some further particulars. The outer part of upper molars of Ungulata being represented by a greater number of cusps, the question is, which cusps are missing in these much worn molars.

So far back as 1873 I described the outer parts of upper molars as being composed of six cusps, which in my figures were designated by the letters *a*, *b*, *c*, *d*, *e*, *f*, proceeding from before backward, and I added that all the differences were to be traced back to the respective position of these six parts to each other and to their relative development.[1] When criticizing these views, Schlosser maintained that *a*, *c*, *d*, and *f* are not essential parts of the tooth, but mere secondarily developed crests or tubercles.[2] However, as Winge had shown in the meantime, in such low mammals as Insectivora and Polyprotodont Marsupialia, these cusps are arranged in two longitudinal series, much more independent of each other than in higher Mammalia. He admits five cusps, and numbers them from before backward 1, 2, 3, 4, 5; cusp 2 corresponding to my *c*, *d*. The first three (1, 2, 3) form the outer, the latter two (4, 5) the inner series, and he further states that the former are the original three cusps of the Mammalian molar, the homologues of the three cusps of Triconodonts.[3] At any rate they are remarkably developed in several upper Cretaceous Mammalia from the Laramie.[4] According to the nomenclature of Osborn, who in his turn considers the outer cusps (-styles) as secondary formations, the five cusps are, always proceeding from before backward, the parastyle, paracone, mesostyle, metacone, metastyle, or, considering their arrangement in two longitudinal series: parastyle, mesostyle, metastyle (outer series); paracone, metacone (inner series).

In Ungulates these different parts are connected together, so that the tooth presents a W-shaped outer wall, usually shallow.



The more a tooth is hypselodont, the more its outer wall becomes flattened, and the folds dividing the cusps tend to disappear; as may be seen by comparing my figures of brachyodont (Figs. 4, 5) with those of hypselodont (Fig. 3) Hyraces, in which I have adopted Winge's mode of numbering the cusps. In the brachyodont teeth 1 and 2 are very prominent, and in both brachyodont and hypselodont Hyraces the fold dividing 2 and 5 is particularly shallow, and tends to disappear in the course of wear, at an earlier date in hypselodont, very late in brachyodont Hyraces; so that very often 2 and 5 become fused together, as is the case in m. 1 of Fig. 3 (in the figure this fusion is not so apparent as in the original). The final result is that in worn molars the fold between 4 and 2 seems to divide the outer wall of the tooth in two equal halves; but the

[1] Palæontographica, vol. xxii (1873), p. 101, pl. vi.
[2] Morphol. Jahrb., xii (1887), p. 102.
[3] Vidensk. Meddel. Naturh. Foren. Kjöbenhavn, 1882, p. 15, pl. iii.
[4] H. F. Osborn, "Fossil Mammals of the Upper Cretaceous Beds": Amer. Mus. Nat. Hist. and Art, vol. xvii (1893), pl. viii.

less worn teeth show that in reality the part of the outer wall anterior to the fold mentioned is composed of two cusps, 4 and 1, the part posterior to it, of three cusps, 2, 5, and 3.

The foregoing statement already partly disposes of the alleged close agreement between upper teeth of hypselodont Hyraces and those of Rhinoceridæ, which has been repeatedly maintained; it has even been said that the former have "the same pattern as those of *Rhinoceros*." The Rhinoceridæ (and Hyracodontidæ) were characterized by Cope as having the "anterior exterior crescent of superior molars more reduced."[1] Osborn has more precisely defined this character of Rhinoceridæ by stating that "the character separating the Rhinoceroses from all other lophodonts is the asymmetry of the external cusps, the metacone being longer than the paracone"; and he adds besides that the anterior lobe arises from the apex of the paracone, just as the posterior lobe arises from near the apex of the metacone.[2]

A notable difference between the upper molars of Hyracidæ and Rhinoceridæ is the absence of cusp 2 (mesostyle), and the fusion of cusp 3 with the metacone in the latter,[3] which accounts for the "elongation of the metacone," and the asymmetry of the remaining external cusps. This asymmetry is due besides to the circumstance, that cusp 4 (paracone) projects more outwards than 5, whereas even in those Hyracidæ in which 2 becomes fused with 5, no asymmetry is the result.

I find that the teeth of both hypselodont and brachyodont Hyraces have the same pattern; the only difference being, as already mentioned, that the outer wall of the former has all the cusps and the intervening folds so reduced that its contour, instead of having the shape of a shallow W, as in the brachyodont teeth, represents a slightly undulated longitudinal line. Besides, there are species of Hyracidæ which are semi-hypselodont, being neither brachyodont nor hypselodont.[4]

As regards the transverse crests or lobes in the upper teeth of Hyracidæ, unworn teeth, whether brachyodont or hypselodont, show each of the two crests incompletely divided into two cusps, the outer smaller ones being apparently the intermediate conules; these very soon become fused with the inner cusps so as to form the crests. In unworn teeth the inner cusps almost touch the outer

[1] Bull. U.S. Geol. Geogr. Surv., vol. v (1879), p. 228; Am. Natur., vol. xiii (1879), p. 771*a*.

[2] H. F. Osborn, "The Extinct Rhinoceroses": Mem. Amer. Nat. Hist., ser. 1, vol. iii (1898), pp. 87, 88.

[3] There is a trace of it in some of the Oligocene Rhinoceroses, as shown in Osborn's figures of *Aceratherium occidentale* and *A. tridactylum*, op. cit., p. 109.

[4] Other characters also, which, like those referred to, have been made use of for dividing the Hyracidæ into two or three genera, prove not to be constant. Thus, a very competent writer, who, as a rule, at least of recent years, is not particularly coy when it comes to the splitting of genera or species, has "come to the conclusion that it is better on the whole to recognize only a single genus for the whole of the Hyraces." (O. Thomas, "On the Species of the Hyracoidea": P.Z.S. London, 1892, p. 52.)

wall (Fig. 4), and at an early stage of wear (Fig. 5) they become fused with the inner part of cusps 4 and 5 respectively, while the intermediate conules, the outer cusps of the crests, tend respectively towards cusps 1 and 2 of the outer wall (Fig. 4) and become ultimately, in their turn, fused with them (Figs. 5 and 3).

When comparing our figures of the Hyrax teeth with the diagram of a *Rhinocerós*-tooth[1] it becomes apparent that in the latter each crest unites with the outer wall in one place only, and this fusion is as a rule brought about by those parts of the crests which correspond to the intermediate conules.[2]

The upper cheek teeth of Hyraces exhibit besides an anterior and a posterior basal cingulum, and, less frequently, an outer one also. All these secondary parts, including the last one, are represented in the molars of *Pliohyrax* (Fig. 2). The main differences between the fossil and the recent teeth, apart from the complication of the fossil m. 3, are the following: (1) The fossil teeth are more bunodont; for, as far as their worn condition permits us to judge, the inner cusps remained independent for a longer time than in recent Hyraces (compare Fig. 2 with Fig. 3). (2) In the fossil teeth the outer cusps (1 and 2), especially the latter, Osborn's mesostyle, are more prominent than in Hyraces. Both these characters point towards a more primitive condition of the fossil teeth.

MEASUREMENTS.

	mm.
Length of the three true molars in the middle line	94
Breadth of skull from sagittal suture to outer margin of orbit (the greatest breadth of the skull would therefore be approximately 210 mm.) ...	105
Breadth of skull between posterior external margins of the infraorbital foramina	90·5
Breadth of palate between anterior parts of m. 1	45
Maximum of vertical height of orbit	43
Long axis of same	46
Height of zygoma below orbit	48
From posterior upper margins of infraorbital foramen to anterior margin of orbit	69

The addition to our knowledge of the genus '*Leptodon*,' due to the skull in the British Museum, does not bring us nearer to the Hyracidæ than the mandible described by Gaudry; for, besides some differences pointed out in the molars, the recent Hyraces differ in their skull from the fossil—(1) by comparatively larger orbits, situated at a lower level, and not so far backward as in the latter; (2) by the anterior border of the orbits being situated either above the anterior margin of the posterior premolar (p. 1), or, in the species with smaller cheek teeth, even above the anterior part of p. 2; (3) by the more anterior position of the infraorbital foramina;

[1] Osborn, op. cit., p. 87, fig. 5.

[2] It seems probable that what is called 'crochet' in the *Rhinoceros*-tooth is the homologue of the posterior intermediate cusp (metaconule); therefore, in those teeth in which the crochet is present as such, the inner cusp of the posterior lobe (hypocone) would appear to join directly the outer wall.

(4) by the bony palate not being prolonged backward beyond the molar series.

A characteristic feature of the Hyraces is revealed by a second skull from Samos, which found its way to the Stuttgart Museum, and has been described and figured by Osborn.[1] "The relationship of *Pliohyrax* to *Hyrax* is . . . . obvious in the enlarged pair of incisor teeth and in the lophoselenodont structure of the molar teeth, which characters respectively determine its subordinal and ordinal position."

In the side view of the Stuttgart skull,[2] drawn from a photograph, the infraorbital foramen appears to occupy the same position as in the cranium of the specimen in the British Museum. In the portion situated behind the foramen, I am quite unable to distinguish between what is bone, what is matrix, and what may be artificial sculpturing of the latter. The only reference to this part in the text is the statement on p. 172, of "the elevated position of the orbits," wherein we have a further agreement with the British Museum skull. A third point in which the Stuttgart fossil agrees with that of London is "the extreme backward extension of the posterior nares."

The antemolars cannot be compared, the only premolar preserved in the British Museum skull (p. 1) being considerably damaged and, besides, out of position (the inner side is turned outwards). However, its molariform pattern and the presence of cusp 2 (mesostyle), as described by Osborn in p. 1 from Stuttgart, are clearly discernible. Of p. 1 and p. 2 the same writer says, that they "present an inward and backward cingular extension of the protoloph which may be a specific character." The same may be seen in much worn premolars (and molars) of recent Hyraces, the explanation being that the cingulum cusp at the opening of the great inner fold becomes fused with the anterior lobe.

Owing to the bad preservation of the true molars in the Stuttgart cranium little information could be gathered from them, but this agrees also with the specimen in the British Museum. "The molars increase in size posteriorly, and are extended well back behind the junction of the zygomatic arch with the face. . . . In the first superior molar . . . a prominent mesostyle is seen separating the external lobes, and these are of the lophoselenodont type of *Palæotherium* and *Hyrax*."[3]

Osborn is of opinion that *Pliohyrax* may possibly be the representative of a new family of the Hyracoidea, a view which is rather corroborated than not by the additional information obtained from the British Museum skull.

The collection from Samos in the Munich Palæontological Museum

[1] H. F. Osborn, "On *Pliohyrax Kruppii*, Osborn, a fossil Hyracoid, from Samos, Lower Pliocene, in the Stuttgart Collection. A new type, and the first known Tertiary Hyracoid": Proc. Fourth Internat. Cong. Zoology, Cambridge, 22–27 August, 1898; pp. 172, 173, pl. ii (1899).

[2] Op. cit., pl. ii, fig. 1.

[3] Op. cit., p. 173.

has yielded to Schlosser[1] an almost complete lower jaw, which he identifies as being of the same species with the skull in the Stuttgart Museum, and he even believes that both may belong to the same specimen. While referring the reader to Schlosser's description of the conformation of the lower premolars, canine, and incisors, and to Osborn's figure (pl. ii, fig. 3) of the upper ante-molars, I wish to recall the fact that from the conformation of the anterior lower premolar of his *Leptodon græcus*, Gaudry had already rightly concluded that the lower canine "a dû être en contact avec la première prémolaire et avoir une faible dimension."[2] This conclusion has been fully borne out by Schlosser's discovery of the Samos mandible.

From what has been ascertained by these successive discoveries, it is now satisfactorily established—(1) That the four fossils in Paris, Stuttgart, Munich, and London belong to a single genus; the name *Leptodon* being preoccupied, as was pointed out to me by Mr. Lydekker, it will have to be known as *Pliohyrax*. (2) That the mandible from Pikermi in the Paris Museum and the skull from Samos in the British Museum are, moreover, the same species, *Pliohyrax græcus* (Gaudry). (3) The mandible at Munich and the skull at Stuttgart, both from Samos, have been shown by Schlosser to be the same species.

Whether all four fossils are one and the same species, may be decided when exact measurements of the Stuttgart skull are available. M. 1 of the London and the same tooth of the Stuttgart specimen are approximately of the same size; but the skull of the latter seems to be somewhat smaller. This may be due either to individual or to sexual variation; I have in my first note pointed out, that the shape of the large incisors in the Stuttgart fossil exhibits a greater agreement with the incisors of female Hyraces than with those of male specimens.

EXPLANATION OF PLATE XXIV.

FIG. 1.—*Pliohyrax græcus* (Gaudry). Brit. Mus., No. M 5,419. Side view of cranium. $\frac{1}{2}$ nat. size.

FIG. 2.—Left upper true molars of same. Nat. size.

FIG. 3.—*Procavia capensis* (Pall.). First and second left upper true molars (m. 1, m. 2). 2 × 1.

FIG. 4.—*Procavia dorsalis* (Fraser). First left upper true molar (m. 1), very slightly worn. 2 × 1.

FIG. 5.—*Procavia dorsalis* (Fraser). First left upper true molar, more worn than in the specimen Fig. 4. 2 × 1.

[1] M. Schlosser, "Über neue Funde von *Leptodon græcus*, Gaudry, und die systematische Stellung dieses Säugethieres": Zool. Anz., xxii, pp. 378–80, 385–7 (1899).

[2] A. Gaudry, op. cit., p. 215.

V.—Note on *Ammonites calcar*, Zieten

By G. C. Crick, F.G.S., of the British Museum (Natural History).

In his work[1] entitled "Die Versteinerungen Würtembergs" C. H. v. Zieten figured and briefly described[2] a species under the name *Ammonites calcar*. The description is as follows:—"Rücken gewölbt, Rückenlinie spornradförmig gezackt; er hat in dem Bau seiner Rippen und dem erhöhten Saum seiner Windungen grosse Aehnlichkeit mit dem vorhergehenden [i.e. *Ammonites bipartitus*, Zieten], unterscheidet sich jedoch von ihm sogleich durch seine einfach gezackte Rückenlinie. Aus dem untern Oolith bei Guttenberg."[3]

In the same work he also figured a species, which he named *Ammonites bipartitus*[4] and characterized in the following terms:—"Rücken flach, Sipho darauf sehr wenig vorstehend, zwischen zwei Reihen schräg gegen einander überstehender Zähne; die innern Windungen von den äusseren stark bedeckt, deren Mitte auf der Seite durch einen erhöhten Saum getheilt scheint, an dessen inneren Seite sich die Rippen einfach in spitzigen Winkeln anlegen, von seiner äusseren Seite dagegen doppelt bis zu den Zähnen seines Randes hinlaufen. Aus dem untern Oolith unweit Guttenberg."

In the British Museum (Natural History) collection [Register No. 37,670] there is an example (see Fig. 1) of Zieten's *Ammonites calcar*, which bears a label to the following effect in the handwriting of Dr. Bruckmann, from whom the specimen was obtained:—"*Ammonites calcar*, Benz. Zieten. Ausserst selten. Ist nach Quenstedt ein kranker *bipartitus*. Brauner Jura ζ, Gamelshausen." On the label there has been written in pencil, in the same handwriting, the letters "[Dr. O.]," signifying Dr. Oppel, as I have been able to ascertain from the labels accompanying other specimens in the

[1] This work was issued between 1830 and 1834 in twelve parts of six plates each, as follows:—

Heft	i, 1830,	pp. 1–8,	pls.	i–vi,	*fide*	Neues Jahrbuch,	1830, p. 404.
,,	ii, 1830,	,, 9–16,	,,	vii–xii,	,,	,,	1831, p. 336.
,,	iii, 1831,	,, 17–24,	,,	xiii–xviii	,,	,,	1832, p. 118.
,,	iv, 1831,	,, 25–32,	,,	xix–xxiv			
,,	v, 1832,	,, 33–40,	,,	xxv–xxx	,,	,,	1833, p. 111.
,,	vi, 1832,	,, 41–48,	,,	xxxi–xxxvi			
,,	vii, 1832,	,, 49–56,	,,	xxxvii–xlii	,,	,,	1833, p. 244.
,,	viii, 1832,	,, 57–64,	,,	xliii–xlviii			
,,	ix, 1833,	,, 65–72,	,,	xlix–liv	,,	,,	1833, p. 624.
,,	x, 1833,	,, 73–80,	,,	lv–lx			
,,	xi, 1833,	,, 81–88,	,,	lxi–lxvi	,,	,,	1834, p. 245.
,,	xii, 1833	,, 89–96 Alphabetical Register, pp. 97–102	pls.	lxvii–lxxii			

[2] Heft iii, 1831, p. 18, pl. xiii, figs. 7*a*, *b*, *c*.

[3] Zieten attributes the species to 'Benz.,' but gives no reference to that author. Probably, therefore, Zieten was the first to publish a description of the species, and must be regarded as its author.

[4] Heft iii, 1831, p. 18, pl. xiii, figs. 6*a*, *b*, *c*.

British Museum (Natural History) that were also obtained from Dr. Bruckmann. The fact that the "species" is very rare and that this specimen has been labelled, "*Am. calcar*, Zieten (unique)," and marked "Zieten coll.," at once suggested a comparison of the example with Zieten's figure. So exactly did it agree with Zieten's figure that I was led to enquire whether Zieten's type-specimen was known to exist elsewhere.

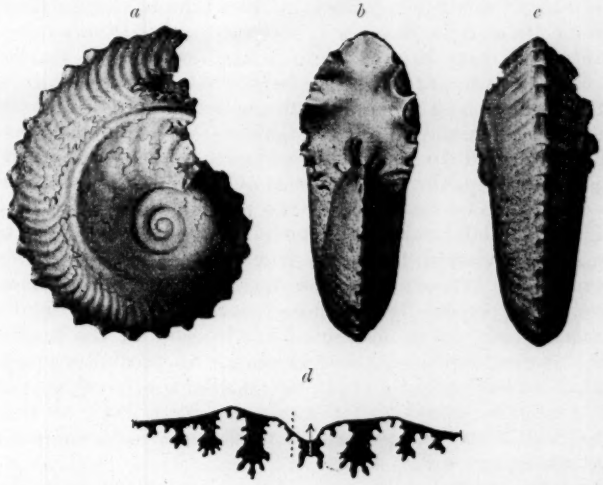


FIG. 1.—Zieten's type-specimen of *Ammonites calcar* [= a deformed example of *Bonarellia bicostata*, Stahl, sp.]. *a*, lateral view; *b*, front view, showing the single row of tubercles on the periphery and the asymmetry of the septal surface; *c*, peripheral view, showing the single row of tubercles near the centre of the periphery; *d*, suture-line, the dotted line near the middle indicating the position of the single row of tubercles, and the short curved lines at each end marking the position of the suture of the shell. Brown Jura ζ (Lower Oxfordian): Gammelshausen, near Boll, Württemberg. Drawn of about twice the natural size, from the specimen in the British Museum (Natural History) collection [37,670].

In one of his papers on "The Fossil Cephalopods of the Museum of Comparative Zoology,"[1] at Harvard College, Cambridge, Mass., Professor Hyatt refers to "specimens from Zieten's former collection," which were sent to that Museum by the Museum of Stuttgart.

Replying to my enquiries, Dr. E. Fraas, of Stuttgart, very kindly informs me that there are only a few of Zieten's type-specimens at Stuttgart, that the type-specimen of *Ammonites calcar* is not among them, and that the large collection there does not contain a single specimen that can be referred to that 'species.' He also states that he does not consider *Ammonites calcar* to be a distinct species, but a deformed example of some other species, possibly of *Ammonites bipartitus*.

Professor Koken, of Tübingen, tells me that, with few exceptions,

[1] Bull. Mus. Comp. Zool., vol. i (1864–9), p. 79.

Zieten's originals are not in Tübingen, but that the collection there contains the two examples of *Ammonites calcar* figured by Quenstedt. According to Zieten's own statement on the title-page, the originals of his "Versteinerungen Würtembergs" were in the collection of Dr. Hartmann, in Göppingen, after whose death they passed, according to Professor Koken, into the hands of Krantz, of Bonn. In all probability, therefore, the specimens were dispersed, and we think there can be no doubt whatever that the example now in the British Museum collection is Zieten's type-specimen.[1] It must, however, be pointed out that this example is labelled in Dr. Bruckmann's handwriting, "Brauner Jura ζ, Gamelshausen," whereas Zieten states that this species came "aus dem untern Oolith bei Guttenberg."[2]

A minute examination of the British Museum specimen—subsequently referred to as Zieten's type-specimen—shows it to be deformed. Firstly, the two branches of the siphonal lobe, instead of being placed one on each side of the median line of the periphery, are both on the left[3] side of the median row of tubercles, so that the septum, when viewed from the front (see Fig. 1*b*), is decidedly unsymmetrical. Secondly, a close examination of the tubercles on the periphery, especially of those near the anterior end of the specimen, reveals an indication of subdivision in the median line, as if each were formed by the coalescence of two antero-posteriorly elongated tubercles. Further, the whole specimen is not quite symmetrical, the left side of the whorl being a little more inflated than the right, and the peripheral tubercles a little on one side of the median line (see Fig. 1*c*).

Quenstedt[4] regarded Zieten's *Ammonites calcar* as a deformed example of *Ammonites bipartitus*, Zieten, and in this opinion was supported by Bronn[5] and Oppel,[6] for both these authors referred *Amm. calcar* and *Amm. bipartitus* to the same species (*Ammonites bicostatus*, Stahl), the last-named author adding in a parenthesis after the reference to *Amm. calcar* the word 'Missbildung.' Giebel,[7] however, regarded *Amm. calcar* as a separate species, an opinion which appears to be shared by Parona and Bonarelli.[8]

On comparing Zieten's figure of *Ammonites calcar* with that of his *Amm. bipartitus* a great similarity in the sculpture is at once

[1] This view is supported by the subsequent discovery in the Museum collection of two more of Zieten's type-specimens (*Ammonites discoides*, p. 21, pl. xvi, figs. 1*a*, *b*, *c*; and *Ammonites polygonius*, p. 21, pl. xv, figs. 6*a*, *b*, *c*), both of which were obtained from Dr. Bruckmann.

[2] The only place of this name in Württemberg that the writer has been able to find is about eight miles due east of Dettingen and is spelt 'Gutenberg.' Gammelshausen is near Boll, which is about nine miles north-east of Gutenberg. There is also a discrepancy about the horizon and locality of the two other specimens in the Museum collection that are believed to be Zieten's types.

[3] The terms 'right' and 'left' are used in a purely morphological sense.

[4] F. A. Quenstedt: "Petref. Deutsch.," Bd. i, Cephalopoden (1846), p. 140; and "Amm. Schwäb Jura," Bd. ii (1887), p. 735.

[5] H. G. Bronn: Index palæont., 1848, p. 33.

[6] A. Oppel: "Die Juraformation," 1856–58, p. 560 (1857).

[7] C. G. Giebel: "Die Fauna der Vorwelt," 1852, p. 567.

[8] C. F. Parona & G. Bonarelli: Mém. Acad. Sci. Savoie, sér. 4, vol. vi, p. 141, 1897.

apparent, and this, together with Zieten's statement that *Ammonites bipartitus* also came "aus dem untern Oolith unweit Guttenberg," suggests a possible relationship between the two forms. This apparent relationship is confirmed by the comparison of Zieten's type of *Amm. calcar* with a normal example of his *Amm. bipartitus*, of which species there are several German examples [1] in the British Museum collection. Several other differences are apparent besides the arrangement of the tubercles on the periphery. Thus, compared with an example of Zieten's *Amm. bipartitus* of about the same size, *Amm. calcar* has more inflated whorls and a slightly smaller umbilicus. This is clearly shown by a comparison of the dimensions of the specimens. Thus the measurements of Zieten's type-specimen of *Amm. calcar* are:—Diameter of shell (excluding spines), 20·5 mm. (100); width of umbilicus, 4·5 mm. (21·9); height of outer whorl, 10 mm. (48·7); height of outer whorl above preceding whorl, 8 mm. (39·0); thickness of outer whorl, 7·5 mm. (36·5): whilst the dimensions of an example of Zieten's *Amm. bipartitus* from the Brown Jura ζ, Beuren, Württemberg [C. 7,267*b*] at the same diameter are:—diameter of shell (excluding spines), 20·5 mm. (100); width of umbilicus, 5 mm. (24·3); height of outer whorl, 9·5 mm. (46·3); height of outer whorl above preceding whorl, (?); thickness of outer whorl, 7 mm. (34·1): and the dimensions of a smaller but slightly more inflated example [22,324*b*] of the same species are:—diameter of shell, 19·5 mm. (100); width of umbilicus, 4·5 mm. (23·0); height of outer whorl, 9 mm. (46·1); height of outer whorl above preceding whorl, 7 mm. (35·8).

Compared with that of *Amm. bipartitus*, the suture-line of *Amm. calcar*, besides being unsymmetrical, presents slight differences in its details (compare Figs. 1*d* and 2), but all these may, we think,

FIG. 2.—*Bonarellia bicostata*, Stahl, sp. Suture-line of normal example for comparison with Fig. 1*d*, the dotted lines near the middle of the figure indicating the position of the row of tubercles on each margin of the periphery, and the short curved lines at each end marking the position of the suture of the shell. Brown Jura ζ (Lower Oxfordian): Balingen, Württemberg. Drawn of twice the natural size from an example in the British Museum (Natural History) collection [39,926].

be attributed to the general deformation of the specimen. As might be expected the greatest difference is in the peripheral portion of the line; the peripheral saddle on each side, especially that on the right in Fig. 1*d*, is much reduced in width, but it, nevertheless, exhibits a subdivision which is clearly comparable with that of the corresponding saddle in *Amm. bipartitus*.

[1] There are four examples (22,324*a–d*) from the Brown Jura ζ, Beuren, Württemberg; one (39,026) from Balingen, Württemberg; and four others (C. 7,267*a–d*) from Germany, but the precise locality of these is not recorded.

On the whole we think there cannot be any doubt that Zieten's *Amm. calcar* is only an example of his *Amm. bipartitus*, deformed in such a manner that the marginal tubercles of the periphery have coalesced into a single row of tubercles occupying nearly the median line of the periphery, just as in the example of *Hoplites tuberculatus* from the Gault of Folkestone, described by the present writer in a previous number (December, 1898) of this Magazine. There are individual differences in *Amm. bipartitus*, among which may be noticed a variation in the prominence of the ridge on the middle of the lateral area, in the number of the marginal tubercles, and in the coarseness of the ornaments. *Amm. calcar* agrees with an average specimen.

Having decided that the type-specimen of Zieten's *Amm. calcar* is a deformed example of his *Amm. bipartitus*, a few words must be added respecting the name of the fossil.

Firstly, in regard to the trivial name. Both Bronn[1] and Oppel[2] considered Zieten's *Amm. bipartitus* to be a synonym of Stahl's *Amm. bicostatus*,[3] and we think there can be no doubt as to the correctness of this identification. Quenstedt[4] refers Zieten's *Amm. bipartitus* and Stahl's *Amm. bicostatus* to the same species, for which, however, he adopts the name *Ammonites bipartitus*. But since Stahl's name antedates Zieten's by some seven years it should stand, and the trivial name of the fossil should be *bicostatus*.

Secondly, in regard to the generic name. There is no difficulty about the generic name of this species, for Munier-Chalmas[5] selected *Ammonites bipartitus*, Zieten, as the type of a new genus, for which he proposed, in 1892, the name *Distichoceras*, without, however, giving any diagnosis of the genus. This was subsequently supplied by Parona & Bonarelli,[6] who gave not only a diagnosis of the genus, but also a list of the forms which they included in it. Cossmann,[7] however, points out that this name is preoccupied by *Distichocera*, of Kirby, and accordingly alters it to *Bonarellia*.

Hence the British Museum example of Zieten's *Ammonites calcar*, which is most probably the type-specimen, is merely a deformed example of *Bonarellia bicostata*, Stahl, sp.

[1] H. G. Bronn: Index palæont., 1848, p. 33.

[2] A. Oppel: "Die Juraformation," 1856–58, p. 560 (1857).

[3] G. Stahl: Corresp.-Blatt Würt. Landwirthsch. Ver., Bd. vi (1824), p. 49, fig. 9. Stahl's description is as follows:—"Er hat eine vertiefte Rückenlinie, deren Seiten nach aussen mit kleinen Zähnen besitzt sind; von jedem Zahn gehen zwei Streifen bis an die in der Mitte der Windungen hinlaufende Streifungslinie, von wo an die andere Hälfte der Windung glatt ist. Er findet sich verkiest bei Gammelshausen im jungern bituminösen Mergelschiefer; erfordert übrigens noch nähere Untersuchung."

[4] F. A. Quenstedt: Amm. Schwäb. Jura, Bd. ii (1887), p. 732.

[5] Munier-Chalmas: Bull. Soc. Géol. France, ser. 3, vol. xx, No. 6, Comp. rend., p. clxxi, 1892.

[6] C. F. Parona & G. Bonarelli: Mém. Acad. Sci. Savoie, sér. 4, vol. vi, p. 139, 1897.

[7] M. Cossmann: Rev. crit. de Paléozool., vol. ii, p. 75, 1898.

VI.—Mr. Hudleston "On the Eastern Margin of the North Atlantic Basin."[1]

By Prof. J. W. Spencer, M.A., Ph.D., B.A.Sc., F.G.S.

THE delay of several months, in replying to Mr. Hudleston's communication relative to the above-named subject, has been due to absence in the field in a distant region, where I was not in touch with the current literature.

In the study of suboceanic topography, it is to be regretted that most of the writers use the hydrographic unit of measure — the fathom—where the investigations have for their object the comparison of the submarine features with those of the land where the unit is in feet. This use of two units dims the comprehension, unless the differential measurements are translated into the same standard.

On nautical charts, the 10- and 100-fathom contours are generally drawn for navigation purposes, and the latter is the only contour-line that usually approaches the suboceanic continental margins. Hence this line is most commonly spoken of as if identical with the submerged margin of the continent. This inaccuracy would scarcely obtain were the measurements in feet adopted. The edges of the submarine platforms vary all the way from 300 to 1,200 feet, though the margins of the outer shelves often reach to 3,000 feet or more.

In the study of the peculiarities of the suboceanic continental margins, contours of 1,000 or 500 fathoms apart are not sufficiently close to bring out the features in an intelligent way, although they may be all that are practicable on a map of small scale. By drawing them at 200 or 300 feet apart, I have found that many difficult features became easily explicable. If Mr. Hudleston had taken the fullest data and contoured the slopes from 100 to 1,000 fathoms on his map of the "British Biscayan Atlantic," with isobars of 200 or 300 feet, it is possible that he would not have found that the soundings "in certain localities round the Bay of Biscay are curious and perplexing." It is such curious and perplexing features as these, made known to a better degree in more favoured regions, which I have studied in large numbers, and which Professor Hull has found and more fully studied off the European coast. But Mr. Hudleston, in his really valuable paper, does not seem to have recognized their importance.

The first striking feature in Mr. Hudleston's paper is his study of the gradients of the suboceanic continental slopes. He has shown a very large number of cases where the declivities at different points amount to from only 1 in 188 to 1 in 7 or 8, except in the Bay of Biscay, where they may be as much as 1 in 4 or 5, and in one case so precipitous as to reach a deepening of one foot in two. His averages are those extending usually over considerable distances of 20 miles or more. The conclusion drawn from them is that the great continental slopes are not

[1] Geol. Mag., Dec. IV, Vol. VI (1899), pp. 97–105 and 145–157.

vertical or nearly vertical precipices, which neither Professor Hull nor I ever stated, and, therefore, much of Mr. Hudleston's labour for the apparent purpose of refutation is lost. But on analyzing his method, it is found superficial only, as it does not give us a true idea of the variable forms and pitch of the continental slope. In other regions, notably the Floridian channel, leading to the Gulf of Mexico, the analyses of the soundings show that the mean slope in no way conveys an impression of the actual form of the deepening of the channel. The floor of the submerged valley is in reality made up of a series of very gentle gradients, or almost horizontal steps, separated by precipitous declivities. The margin of the Mexican plateau—back of Vera Cruz—has an elevation of somewhat more than 8,000 feet above the sea, or 6,500 feet above the inner margin of the coastal plain. Following up one indentation, the average declivity is only 1 in 30, while at another point it is 1 in 10. But these averages do not suggest the declivity of the great escarpment, for the slope is made up of a series of steep gradients, often 1 in 3 or 4, or perhaps in places 1 in 2, separated by zones of comparatively small pitch. The soundings along the Atlantic margin, which Mr. Hudleston has studied, may not have been close enough to reveal the steps, although he has shown that in the Bay of Biscay the declivities are precipitous. It appears to me that his citations of the mean declivity of the continental slope scarcely become a criticism of the characteristics of the great drowned valleys, as pointed out by Professor Hull and myself.

A second feature made by his studies of the suboceanic continental slope is that it is continuous over great distances (which is perfectly correct), and that the Norwegian basin is an extension of that of the North Atlantic; or, as expressed by him, "it is obvious from an inspection of the accompanying map that the eastern part of the North Atlantic, the Norwegian Atlantic, and a portion of the North Polar ocean, all belong to one and the same great geosynclinal depression, which has been partly interrupted by volcanic extravasation, more especially in the region between Shetland and south-east Greenland." This view cannot pass unchallenged. The ("eruptive") barrier extends *practically* from Europe to Greenland; and between points where the depth of even the valley-like extensions of the basins is 12,000 feet the breadth of the barrier is 600 miles or more, and it rises to within 2,000 feet of the surface of the ocean. Such a barrier, rising 10,000 feet out of 12,000 feet, is certainly too stupendous to be considered as only a partial interruption in one oceanic basin. As a matter of fact there are two basins (and the more northern is apparently continuous with that of the great Polar Sea), just as the Caribbean and Mediterranean basins are distinct from that of the Atlantic. If we could regard this Icelandic plateau in the manner that Mr. Hudleston does, as a volcanic extravasation, interrupting the continuity of the Atlantic basin, it might obviate the necessity of explaining the valley-like features of the ridge. He further says: "to the westward, beyond the centre of Lightning channel ('which is that eastward of Faroe

Islands') all the known land and presumably most of the submerged land is of igneous origin." This last conclusion, applied to a barrier nearly a thousand miles long and hundreds of miles in width, seems to me a more extravagant conclusion than the amount of changes of level postulated by Professor Hull and myself. The central American barrier, between the Caribbean Sea and the Pacific Ocean, is of even smaller proportion, and those parts of it which are above water show a prevalence of volcanic rocks of comparatively recent date; yet from beneath these rocks old crystallines are occasionally exposed, and remains of the earlier Tertiary formations are widely distributed. So, too, it is hardly justifiable to suppose that there is no diversity of formations on the Icelandic plateau, which would suggest continental features; accordingly, the student of submarine topography is forced to analyze the land-like forms of the ridge, all the more so as the valleys and their tributaries, cirques, and embayments suggest that they were fashioned in the same manner as other submarine and subaërial valleys, far away from great plateau eruptions.

A third feature noticeable in the paper is a general overlooking of the detailed form of the edge of the platform, where the soundings "are very irregular and puzzling, so much so that it is not easy to deduce any mean angle of inclination." There is no special reason why a *mean* slope should be found. It is the study of such "curious and perplexing" features which has given rise to the bold hypothesis of tremendous changes of level of land and sea. Therefore, so long as Mr. Hudleston overlooks the amphitheatres and valley-like indentations of thousands of feet in depth, dissecting the continental margins, he has not the facts before him to warrant the *ex cathedra* conclusion—that stupendous changes of level have not occurred.

However, Mr. Hudleston has spoken of the Norwegian channel from the Skager Rack, which has long been known and written upon. Its breadth seems to be greater than he is prepared to accept as that of a valley, although it is a strong feature from Christiania Fjord, rounding the point of Norway, and extending 500 miles to the oceanic abyss. Its breadth should be no difficulty, for it is not as great as that of the lower St. Lawrence merging into the Gulf of the same name; and the flood plains of the land-valley of the lower 500 miles of the Mississippi are from 30 to 80 miles wide, with its lower portion now buried by sediments to a depth of 1,000 feet. This Norwegian channel has a depth, near its head, of 2,658 feet, but farther seaward, as it is crossing the subcoastal plain, its depth is reduced to 960 feet, unless the soundings do not reveal the deepest portions of the channel. He considers this feature "unfortunate" for the theory of its being the course which drained the Baltic valley, and says: "the river of the Baltic, therefore, must have had some difficulty draining towards the Atlantic under these circumstances." Professor Hull and Professor Bonney have answered these points. As shown by them, it is in a region of glacial distribution; so that an easy explanation is seen in the unequal filling of the old

valley, such as is known to have frequently occurred. As an illustration of such obstruction, the ancient Laurentian valley between Georgian Bay (eastern portion of Lake Huron) and Lake Ontario is entirely obliterated, not merely by being filled with drift, but also by high transverse ridges. These Pleistocene accumulations have a depth of 500 to 1,000 feet. Yet the portions of this ancient valley, beyond both sides of the drift filling, are still open channels beneath the waters of the lakes. Again, the differential elevation may in part have raised the barrier across the Norwegian channel. Such a result has been the case in mostly closing the outlet of the basin of Lake Ontario, which is 738 feet deep; this differential elevation being recorded in the tilting of the beaches adjacent to the lake, but now raised far above it. As the development of this submerged channel is a feature very much greater than its partial obstruction, the hypothesis of its subaërial origin has in no wise been overthrown by Mr. Hudleston's superficially-formed conclusion, touched with sarcasm: a conclusion based upon one feature, namely, obstruction, which is much easier of explanation than the occurrence of the submerged Norwegian valley itself, if it were not of subaërial origin. Accordingly, the grand old valley is not yet placed without the pale of the laws of uniformity, which prevail in both subaërial and submarine valleys.

My conception of the proper treatment of the 'irregularities' in the continental margin, beneath the waters of the Bay of Biscay, differs greatly from that of Mr. Hudleston. For instance, at a point 100 miles south-east of La Chapelle bank, his statement is:—"For at one spot 600 fathoms is marked just outside the 100-fathom line; while at another, further out to sea, a distance of about seven miles, separate soundings of 880 fathoms and 2,100 fathoms respectively, thus giving a slope of 1 in 5, or 11°. In the latter case, the irregularity is not connected with the edge of the 100-fathom platform, but may be said to belong to abyssal depths." His explanation bears only upon the question of the irregularity of the slopes, and does not convey to me any impression that he was making any study of the cirque-like indentation. I should describe the phenomenon as shown upon his own map as follows:—There is a sounding of 3,600 feet (600 fathoms), located a few miles within the line connecting the 600-foot depths on either side, suggesting a cirque in the great continental slope. The trend of this slope on the eastern side of the cirque (or, more correctly speaking, amphitheatre) appears to turn so as to form an embayment due south of the 3,600-foot point, reaching to a depth of 6,420 feet, with a promontory to the east of it rising 860 feet above its floor at this point; thus showing a great amphitheatre-like valley continuing outward from the 600-foot platform. Beyond this point the 12,000-foot contour also shows a marked indentation, corresponding to a continuation of this valley, noted at depths of 3,600 feet and 6,420 feet, although Mr. Hudleston forms a contrary conclusion. At the head of the amphitheatre, there appears to be a precipitous declivity of about 3,000 feet, but from the foot of this declivity the mean gradient of the valley is about

1 in 30; while if I went farther and compared the gradient of the floor of the indentation with the pitch from the promontory upon its eastern side, I should find it 1 in 5 as given by Mr. Hudleston. He has studied only the angle of descent of the continental slopes: I have studied the sculpturing of the slopes, with their valleys and gradients.

This amphitheatre-like indentation, by itself, would not be a strong point, as the data are scanty; but when the feature is one of constant recurrence, and fuller information concerning such features is often obtainable elsewhere, as Professor Hull has shown to be the case at numerous points off the coast of France, Spain, and Portugal, experience makes easy the interpretation of the fragments of drowned valleys which have been recovered.

Turning now to the Fosse de Cap Breton, at the angle of France and Spain, the data are very much fuller, and Mr. Hudleston's treatment is happier, but still falls far short of the facts, as shown upon the chart, which he has reproduced, and therefrom my conclusions reach farther, and fully support the investigations of Professor Hull.

The Fosse dissects the submarine platform, limited by the 600-foot contour, which has a breadth of about 30 miles. It has a depth of 1,260 feet near its head. Farther seaward, the next sounding is 180 feet less, as also two other soundings are less, but these are not in the centre of the channel, as illustrated. Only fuller soundings would prove a barrier, but even then an obstruction by river deposits is what might occur. Another chart,[1] which I have seen, gives more conclusive data than the illustration here analyzed. A little farther outward, the depth has increased to 2,694 feet (on the side of the channel), then to 3,660 feet near the centre, and still farther to 3,750 feet. From this section, Mr. Hudleston passes to "35 miles" farther seaward, and finds soundings of 1,500 fathoms in an outer platform submerged to about 900 or 1,000 fathoms. He then ascertains the mean slope of the side (1 in 7, which is about 750 feet per mile). He cites an example, given by Professor Milne, of the submarine cables being buried by the fall of the vertical walls overhanging them. He concludes as follows: "there are several indications that this depth of 1,500 fathoms represents a hole rather than a channel, for the next sounding seaward shows only 1,250 fathoms." But this last sounding is eight or ten miles from the 1,000-fathom line adjacent to the coast, leaving plenty of room for the intervening channel to reach an additional depth of 250 fathoms. Indeed, to the north-west of the 1,500-fathom hole, and landward of it, the lateral depth is 1,370 fathoms. Between this hole and the Fosse de Cap Breton, already established, there is a chain of soundings of 1,170, 1,107 (this is midway between the 1,500-fathom "hole" and the 625-fathom depth of the fosse), and 915 fathoms, between which and the 625-fathom sounding there is one of only 500 fathoms. In the application of these soundings, it must be

[1] "Submarine Gullies," etc., by Henry Benest: Geogr. Journ., October, 1899, p. 405. The soundings on the Admiralty Chart are very numerous.

borne in mind that the locations are not accurate, and that in offshore hydrography, errors of location up to five miles are permissible (though usually much less) even in good work, when the soundings are made at different times. Consequently, the windings of the valleys are only approximately located, and there may even appear interruptions, but their depths at various points are correct. Under all these conditions, I am forced to give value to the intermediate soundings passed over by Mr. Hudleston, and reach only one conclusion, which is Professor Hull's—that the Fosse de Cap Breton is a continuous valley to beyond the depth of 1,500 fathoms, and from the character of the steep sides it appears to partake of the nature of a cañon. From the soundings, the floor of the fosse, as thus extended, seem to be characterized by three steps, separated by long intervals where the slope is reduced to a few feet per mile, while the mean declivity of the intervening steps is 200 feet per mile. If fuller soundings were made, the steps might be found more abrupt, and there might be a larger number revealed. Mr. Hudleston's explanation of the 1,500-fathom sounding as being a "hole rather than a channel"—an expression used similarly elsewhere—would appear to be a refuge from the valley hypothesis, unless it is shown how such are formed, especially when there is a succession of them.[1]

I wish to correct a criticism. He says, "that Professor Spencer, having long studied the Caribbean Sea—perhaps the most unstable region of the earth—appears to have an exaggerated notion as to epeirogenic uplifts on both sides of the Atlantic"; and he further objects to the hypothesis that the Rockall embayment, west of Ireland, has been fashioned by atmospheric agents, and suggests that both it and the Lightning channels, and the deeps of the Norwegian Atlantic were due to tectonic causes. Whatever were the causes of the basin, the claims of Professor Hull and myself are only that the barriers were once land, which were moulded by atmospheric agents, producing the valleys dissecting them.

I fear that my critic's impression of the instability of the Caribbean region is very much magnified. It is now certainly established that the principal changes of level, since the early Tertiary period, over that region—vastly larger than the Norwegian basin—have occurred with remarkable persistency, though varied in magnitude. And these changes have extended to the North American continent, and continued northward to regions considered the most stable. I suspect that the most of these changes are represented in the eastern Atlantic, which the evidence brought out indicates. At no time have I stated that the same individual oscillations extended to both sides of the Atlantic, as the oscillations may not prove to have been absolutely synchronous. They may yet be found to have alternated. The changes may also have been more complete in one region than another.

[1] For a restoration of this submerged river channel as determined by Prof. Hull, see Geogr. Journ. for March, 1899, with map.

As to the Rockall embayment and Lightning channels, it may be said that only a brief notice was taken of these by me in my preliminary paper,[1] cited by Mr. Hudleston. In a general way I called attention to the deep valley-like depressions dissecting the submarine Icelandic plateau in both directions. These and the Rockall embayment, with their tributary amphitheatre-like valleys, were regarded as only the more advanced forms of atmospheric sculpturing of the margins of an elevated plateau, similar to land features, of which plenty of examples can be given. But the occurrence of the submarine plateau is explained by Mr. Hudleston as an igneous extravasation, while the dissection of the drowned barrier by deep valleys he attributes to tectonic causes. But he does not even compare the adjacent submarine features (as, for instance, the fjords and their tributary amphitheatres) with like forms of the basaltic plateau of the Faroes, dissected into islands by valleys and fjords, with cirques of 2,000 feet in depth. Neither the hypothesis of the general igneous origin of the Icelandic plateau barrier, nor that of the tectonic origin of the valleys, subsidiary to the plateau formation, does he support by evidence, and in substituting his explanations for the hypothesis of subaërial sculpturing of a former land, he brings back upon himself the *onus probandi* of sustaining his theory.

Mr. Hudleston sums up eight conclusions, and these by themselves would have been mostly accepted by Professor Hull and myself. But the details of the paper appear more strongly to have for their object the discrediting of the hypothesis of great changes of level of land and sea. I thank him for the trouble he has undertaken in bringing out so many points, and producing such good illustrations. It has enabled me to point out some of the methods of investigation adopted by Professor Hull and myself, and I trust that it may be of use to other students. But in nothing that he has shown does there appear testimony against the correctness of conclusions by Professor Hull concerning the great changes of level of western Europe in late geological times. The evidence makes me believe with Professor Hull that the submerged plateaux, with gently undulating topography, or rounded and flattened forms, were old land surfaces, largely brought into being by the laws governing the base-level of erosion during the very long Mio-Pliocene period. Some of the broader valley features may have been produced during some portion of the same period, but, generally speaking, our theory is that the deep channels dissecting the drowned plateaux were formed during a subsequent epoch of high continental elevation, or were reopened and enlarged in it. The evidence in America places the great elevation after the time of the establishment of the modern molluscan life, but before the epoch of the accumulation of the glacial deposits: approximately, about the commencement of the Pleistocene Period. Then the older valleys were being enlarged, and the bounding slopes were being dissected by receding cañons and amphitheatres, which

[1] Read before the Meeting of the British Association, 1897: GEOL. MAG., Dec. IV, Vol. V (1898), pp. 32–38.

were slowly developed into great and deep channels. We may not have sufficiently distinguished all the older from the newer features. As the amount of erosion performed may seem too great for the supposed period of high continental elevation, we are willing to concede that some of the continuations and enlargements of the more restricted channels, or the embayments terminating them, may be older features, even possibly due in part to tectonic causes, whatever such may be; but this is a question beyond the confines of our present investigations. On account of the great slopes being indented by the newer physiographic forms, we point out the evidence of the subsequent stupendous elevation of the land. We may have to concede to the Pleistocene period a really longer duration than has been popularly supposed. The growth of the valleys, under conditions of variable rainfalls on the elevated plateaux, does give rise to such features as we now find dissecting the submarine platforms; and the denudation under conditions of stupendous changes of level would accelerate the excavation of the valley features, or modify them, as described by Professor Hull and myself.

In place of pointing out the remarkable submarine holes and burying the observations in the tomes of some learned society, we have collected the phenomena and bound them together by a working hypothesis based upon the grammar of geomorphy; a new science as yet not generally mastered, with results at first startling, although they only give expression to some of the changes of land and sea, as taught by Lyell. Our imperfect studies have been met by observations from a different standpoint, as if we did not accept them in the common way; consequently, I do not see that any unanswerable objection has yet been raised to our conclusions. Hardly even enough to spur us on to seek for fresh confirmatory facts. Mr. Hudleston would doubtless drift along with us if he would give the subject the attention which it deserves; and already he says that he is not prepared to deny the connection between Europe and Greenland in mid-Tertiary times, though he fails to see any necessity for it. It was in the mid-Tertiary times that we suppose the great undulating features of the Icelandic bridge began to be formed. I take it that further studies must lead him to distinguish between these features and the deep channels with their tributaries, cirques, etc. But until this differential interpretation of the forms is used, the great changes of level of land and sea in late geological times will doubtless appear startling. Whatever agnosticism there may be concerning the correctness of our conclusions, so long as we are met by hypotheses substituting that of subaërial erosion, it falls upon the advocates of such hypotheses to sustain them with facts. While the changes of level of 3,000 feet would perhaps meet with almost general acceptance, we have not been shown any reason why this limitation should be made, when the valley-like features extend to depths of 9,000 or 12,000 feet, as found by both Professor Hull and myself.

NOTICES OF MEMOIRS.

I.—On a Proposed New Classification of the Pliocene Deposits of the East of England. By F. W. Harmer, F.G.S.[1]

THE term Red Crag, including as it does beds differing considerably in age, is vague, and, when we attempt to correlate the East Anglian deposits with those of other countries, inconvenient; the Scaldisien zone of Belgium, with its southern fauna, for example, representing one part of it, and the Amstelien of Holland, in which northern, and even Arctic, mollusca are common, another. It seems desirable, therefore, while retaining it for general use, to adopt for its various horizons some more definite and distinctive names.

The Upper Crag deposits arrange themselves geographically in horizontal rather than in vertical sequence, assuming always a more recent as well as a more boreal character as we trace them from south to north. They are the littoral accumulations of a sea which was from time to time retreating in a northerly direction.

The classification now proposed, which is based on palæontological evidence, is as follows:—

	Older Pliocene.	
Lenhamian	Lenham Beds (Zone of *Arca diluvii*)	Diestien Sands. Waenrode?
	Newer Pliocene.	
Gedgravian	Coralline Crag ...	Zone à *Isocardia cor.*
Waltonian	Essex Crag.	
Walton horizon	... (Zone of *Neptunea contraria*)	Scaldisien.
Oakley horizon	... ,, ,, ,,	Poederlien.
Newbournian ...	Red Crag of Newbourn, Sutton, and Waldringfield	Amstelien.
Butleyan	Red Crag of Butley and Bawdsey (Zone of *Cardium Groenlandicum*)	Amstelien.
Icenian—Lower horizon	... Norwich Crag, Southern part.	
Upper horizon	... ,, ,, Northern part (Zone of *Astarte borealis*)	
Chillesfordian	(Estuarine) Chillesford Clay and Sands.	
Weybournian ...	Crag of Weybourne and Belaugh (Zone of *Tellina balthica*).	
	Forest-bed (so-called) Series.	

An analysis of the characteristic mollusca of the different divisions respectively of the Crag here suggested shows a gradual diminution of the percentages of extinct and southern forms and a gradual increase in northern and recent species. The difference between the Gedgravian (Coralline Crag) and Waltonian is shown to be less than has been supposed, and the former is here grouped as Newer instead of as Older Pliocene, as hitherto.

The Crag of Oakley, near Harwich, from which the author has recently obtained nearly 300 species of mollusca, belongs to an horizon different to anything previously described, and serves to bridge over the interval between the Crag of Walton-on-the-Naze and the Red Crag of Suffolk. Its fauna closely resembles that of

[1] Read before Sect. C (Geology), British Association, Dover Meeting, Sept. 1899.

Walton, but contains some boreal and Arctic species unknown from that place, including *Neptunea antiqua* (dextral), *N. carinata*, and *N. despecta*, and represents the period when northern forms were first beginning to establish themselves in the Crag basin. It is approximately and partly equivalent to the Poederlien zone of Belgian geologists.

The Red Crag beds, the fossils of which are, with few exceptions, the drifted and stratified shells of dead mollusca, seem to have been deposited either against the shore or in shallow water in proximity to it, in land-locked bays or inlets. The position which these inlets successively occupied was from time to time shifted towards the north, in consequence of the upheaval of the southern part of the Crag area described by the author in a former paper.[1] These inlets were silted up, one after another, by masses of shelly sand, but as far as the evidence goes the beds composing the different zones do not overlap. The Waltonian deposits are confined to the county of Essex, the Newbournian occupying the district to the north of the river Stour, and the Butleyan beds occurring along a narrow belt extending northwards from Bawdsey at the mouth of the river Deben. The Icenian deposits which are found to the north of Aldeburgh are shown by their molluscan fauna to belong to a period considerably more recent than any part of the Red Crag. They cover an area 45 miles by 20 in extreme breadth, and in one place are nearly 150 feet in thickness, but they are not anywhere known to be underlain by beds of Red Crag age. In the northern part of the Icenian area *Astarte borealis* occurs, and this species seems to mark a slightly more recent horizon of this zone. The Weybournian Crag, containing *Tellina balthica*, is only known to the north of Norwich, and extends from thence to the Cromer coast. The author now believes that these latter beds are distinct from and of older date than the Westleton Shingle of Prestwich.

II.—On the Origin of Lateral Moraines and Rock Trains.[2]

By J. Lomas, A.R.C.S., F.G.S.

In dealing with the accumulations of fragmentary materials associated with glaciers it is necessary to distinguish between deposits which are stationary and the débris riding on or moving with the ice.

The latter, reviving a term used by Rendu, will be referred to as 'rock trains,' and the meaning of 'moraines' will be restricted to stationary deposits, either lateral or terminal.

Lateral moraines are not necessary adjuncts to glaciers. Their distribution, which appears capricious, really conforms to a well-defined law. In glaciers with a straight course, they are feebly, if at all, developed, whereas those moving through winding channels have lateral moraines developed in their concave bends. The débris carried by a glacier either in the ice or on the surface gradually

[1] Quart. Journ. Geol. Soc., vol. lii (1896), pp. 773.

[2] Abstract of a paper read before Section C (Geology), British Association, Dover Meeting, September, 1899.

works towards the side in such places where motion is retarded and carrying power reduced. In this respect they conform exactly to the action of rivers which deposit material in their inner bends.

Rock trains may appear suddenly in the middle of a glacier or at the junction of two streams. The first are undoubtedly caused by the erosion of subglacial spurs or crags. Those formed at the point of union of two glaciers are usually regarded as being formed by the joining together of two lateral rock trains.

There are cases, however, where rock trains are formed at the junctions of glaciers, and no lateral rock trains fringe the tributary glaciers. In front of the rocky islands or spurs which separate the glaciers at the point of confluence, a hollow is always seen in which a lakelet often exists. This is the counterpart of the hollow on the down-stream side of a river after passing under a bridge supported by piers.

Objects carried by rivers tend to accumulate in this hollow, and may linger there a long time before they join the main current and get carried away.

Thus rock trains may be formed by débris being thrust out of glaciers at similar places where motion is small. In these instances the fragments are probably torn off under the ice from the flanks of the dividing spurs, and they may be compared with those originating in the middle of a glacier.

REVIEWS.

I.—Geological Guides to Pomerania and Bornholm. By W. Deecke. "Geologischer Führer durch Bornholm." 8vo; 130 pp. and map. "Geologischer Führer durch Pommern." 8vo; 131 pp. Nos. 3 and 4 of Sammlung Geologischer Führer. (Berlin, 1899: Gebr. Borntraegger.)

DR. E. GEINITZ'S guide to Mecklenburg and that of Dr. Beck to the section of Saxon Switzerland south of Dresden have already given a favourable introduction to Borntraegger's series of geological guides. The two next volumes in the series are worthy of their predecessors. They are practical in method, clear in style, and while they are written in language sufficiently popular to be understood by any intelligent tourist, the information is sufficiently precise and definite to give a geologist a clear idea of the geological features of the districts described. Both guides are on the same plan. They begin with a brief account of the topography of the districts; this introduction is followed by a longer general sketch of the stratigraphical geology. The reader, having thus been told what there is to be made out in the district, is informed exactly where to find and how to interpret the available evidence. The books close with a list of the more important geological works on each district and with a full index.

The two districts, though not far distant geographically, are very distinct geologically. Bornholm consists of a granite massif,

intersected by diabase dykes and with a fringe of Lower Palæozoic and Mesozoic rocks along the southern coast. The stratified rocks include Cambrian sandstones and 'schiefer'; an Ordovician *Orthoceras* limestone; *Trinucleus* and graptolite shales; and some Silurian graptolite beds. The Upper Palæozoic is unrepresented. Of the Neozoic series there are only a bed of Lias and a Lower Senonian Greensand and Chalk. The glacial beds are important, and are interpreted as belonging to two Glacial epochs — a first period of complete glaciation, and a second glaciation in which ice occurred only on the low-lying borderlands of the island.

The guide to Bornholm is accompanied by a clearly printed coloured geological map on the scale of 1 : 100,000.

Professor's Deecke's guide to Pomerania is necessarily briefer and less complete than his little monograph on Bornholm. The geological series in Pomerania includes beds of Lias, Dogger (Bajocian and Callovian), Kimmeridgian, Cenomanian, Turonian, Senonian, Oligocene, and Miocene. Probably the most important member of this series is the Schriebkreide of Campanian age (*Mucronatus* zone) of the island of Rügen. The principal Cretaceous sections on that island are described, and a map of north-eastern Rügen is a further guide to the best collecting-grounds. The glacial deposits belong to two series, the first being the puzzling Drifts of the Island of Rügen, whose origin and relations have been a vexed question in North German glacial geology from the days of Lyell's description in 1837 until the recent papers of Professor Bonney and Mr. Hill. The second group of glacial deposits belongs to the great terminal moraine of the Baltic Plain.

Professor Deecke is to be congratulated on his guides, which will be useful to geologists and tourists and especially to geological teachers and their students.

MEMOIRS OF THE GEOLOGICAL SURVEY.

II.—THE GEOLOGY OF THE COUNTRY AROUND DORCHESTER. By CLEMENT REID, F.R.S., etc. 8vo; pp. 52. (Printed for H.M. Stationery Office, London. Price 1s.)

THIS Memoir, which is intended to accompany the New Series Geological Survey Map, No. 328, deals with the subject much more fully than do the previously published Memoirs by the same author on the Geology of Bognor, Bournemouth, and Eastbourne. This is as it should be. In such Memoirs we look for a fairly complete account of the geology of the area included within each Survey map, and for a record not only of what the Survey geologists have done, but of what others have done also.

Upper Jurassic rocks and Wealden beds occupy a very small portion of the area described in the work before us; the Upper Cretaceous, Tertiary, and later deposits form nearly the whole of the ground.

The Gault and Upper Greensand are grouped together, under the name Selbornian (as used by Mr. Jukes-Browne); and these

deposits, as well as the Lower, Middle, and Upper Chalk, with their palæontological zones, are duly described. The Reading Beds next receive attention. These consist partly of coarse sand and grit, with small splinters of flint and with bands of the characteristic red-mottled clay; but westwards the deposit passes into a subangular flint and chert gravel with a few Palæozoic pebbles. An extraordinary number of swallow-holes occurs in the district of Puddletown Heath and Bryant's Puddle, to which attention was directed many years ago by the Rev. Osmond Fisher. Their occurrence in the Reading Beds is attributed by Mr. Reid to the fact that the strata overlying the Chalk comprise freely permeable sand and gravel with bands of clay. The masses of impersistent clay have served to direct the rainfall to certain spots, whence it descended into and dissolved the Chalk.

The London Clay would hardly be recognized by one whose experience was confined to the London area. In the Dorchester region it consists of sand and sandy loam with septarian ironstone. More interest attaches to the Bagshot Beds, on the extent and composition of which much new light has been thrown by Mr. Reid. By an attentive study of the small mineral fragments in unmistakable Bagshot Sands he has been able to trace the equivalents in coarse gravels, which in some cases have been regarded as Drift; moreover, he has shown that westwards the Bagshot Beds overlap the London Clay and rest directly on the Chalk. The evidence obtained tends to confirm the view expressed by Mr. Starkie Gardner, of an Eocene river flowing from the granitic and Palæozoic districts of Devon and Cornwall, and bringing coarse detritus as well as impure china clay into the regions of Dorset and Hants.

An interesting observation made by Mr. Reid is on the softening of Greensand chert. He noticed fragments so soft that they looked like pebbles of pipeclay, though they soon harden on exposure. This, as he remarks, "will explain the curious way in which the fragments are sometimes dented by each other and pitted by sand-grains."

Among other subjects of interest are the Pliocene deposits of Dewlish, which have been worked out very fully by Mr. Mansel-Pleydell and Mr. Reid. The various superficial deposits, the clay-with-flints, plateau gravels, and more recent alluvial deposits are likewise described.

REPORTS AND PROCEEDINGS.

Geological Society of London.

The first Meeting of the present Session, 1899–1900, was held November 8th, 1899. W. Whitaker, B.A., F.R.S., President, in the Chair. The following communications were read:—

1. "On the Cornish Earthquakes of March 29th to April 2nd, 1898." By Dr. Charles Davison, M.A., F.G.S.

The importance of these three slight earthquakes lies chiefly in

the unusually clear evidence that they furnish with regard to the origin of the double series of vibrations in one of the shocks, and to the continuous displacement of the seismic focus along the surface of the originating fault. The second earthquake—that of April 1st—was the strongest of the series, and the account of it is based on 89 records from 56 different places. Two distinct shocks were recorded at 25 places, the second being the stronger. The focus of the first earthquake was about a mile in length; that of the second was probably not less than five miles, and its centre being about a mile E. 33° N. of the former, it probably included the focus of the first earthquake. The focus of the third shock was probably included in that of the second. The strike of the rocks near Mullion, a thrust-plane hading to the south-east, the strike of the lodes near the epicentre, and several elvan-courses—are all parallel to the isoseismal axes, or nearly so. Besides the focal transference along the strike of the fault-surface, the double series of vibrations gives evidence of transference down the hade of the fault-surface, the focus of the earlier shock being at a higher level than that of the second.

2. "On the Geological Structure of Portions of the Malvern and Abberley Hills." By Professor T. T. Groom, M.A., D.Sc., F.G.S.

This paper is in continuation of one on the Southern part of the Malvern Hills already published by the Geological Society. In it descriptions are given of the exposed rocks of the Malvern Range from Swinyard Hill to North Hill, the district of Cowleigh Park, Martley, Woodbury, Wallsgrove, and the neighbouring tract of Coal-measures. The Silurian rocks west of the hills are almost invariably inverted, and the Malvernian rock frequently can be found to be overthrust on to them. In several cases there is reason to suspect that slips of Silurian rocks are caught in infolds among the Malvernian rocks. The author concludes that the whole of this district, May Hill, the Old Red Sandstone tract to the west, the coalfields of the Forest of Dean, South Wales, and Bristol, and the Tortworth district, are traversed by a series of related folds, whose axes run in two chief directions intersecting at a considerable angle: the axial planes of one set tend to dip eastward, and of the other in a southerly direction. Overfolding has taken place frequently from the east, less frequently from the south; and this inversion affects the south as well as the middle and north of the Malvern range. The Archæan rocks are thrust on to various members of the Cambrian System in the south and of the Silurian System in the north. The overthrusts are more closely connected with a later movement than with the first folding of the rocks, and while they have not materially altered the nature of the rocks concerned, they have in some cases resulted in the production of schists (mylonites). In some cases a secondary folding has affected the thrust-planes. The intensity of the folding diminished west of the old ranges. The chief movement appears to have progressed in sections from north to south, and the western fronts of different sections show some tendency towards convexity in the direction of movement. While

the rocks affected by great movement range from the Archæan to the Lower Coal-measures, the Upper Coal-measures and Permian rest relatively undisturbed on the denuded rocks of the range: thus the range is a member of the Hercynian system produced during Coal-measure time, and probably the two approximately rectangular directions of movement were practically contemporaneous and were produced during the limited interval between the deposition of the Lower and Upper Coal-measures. There is no evidence to prove that the Malvern and Abberley Hills formed part of a coast-line against which the Triassic beds were deposited; for the Upper Bunter Sandstone forms the base of the Trias throughout the district and rests unconformably on the Haffield Breccia, together with which it passed unconformably over the site of the West of England Chain. The present position of the Permian and Trias on the east of the hills is due to a post-Liassic fault of moderate downthrow, which tends to run parallel to the western front of the old range.

CORRESPONDENCE.

THE LIMESTONE KNOLLS OF CRAVEN.

Sir,—According to Mr. Marr the limestone knolls in Craven are due to the rock having been squeezed up, under intense lateral pressure, through the overlying shale. If this be the case, we should find the knolls most pronounced where the pressure has been greatest. Now the pressure, as proved by excessive folding, was greatest along what is now the Skibeden Valley, between Skipton and Wharfedale, but there are no knolls there. The knolls are confined to the region of Thorpe, where the rocks are not much folded and have therefore not suffered great pressure. As the knolls, then, do not occur where, according to the theory of Mr. Marr, they ought specially to be found, the theory cannot be true.

J. R. Dakyns.

Pen-y-Gwrych, Llanberis.
November 3, 1899.

SUBMERGED PHYSICAL FEATURES OF THE MEDITERRANEAN BASIN.

Sir,—Since my return from the Continent I have been engaged in tracing out the physical features, by means of isobathic contours, of the western portion of the Mediterranean, and not without some interesting results. Considering the essential difference in the physical conditions of the Mediterranean and the Atlantic—that is, of an inland sea, with numerous large islands, and the vast sweep of an ocean almost unbroken through a thousand miles from the British Isles to the Straits of Gibraltar—we may well be prepared for differences in the submerged features of each; although it may be assumed that any changes of level which the eastern borders of the Atlantic can be shown to have undergone have been shared by the western portions, at least, of the Mediterranean. The great changes of level, amounting to thousands of feet vertical, which are indicated by the slopes of the continental platform and its intersection down to its very base of 1,000-1,500

fathoms by old river-valleys, must have extended far eastward as well as westward; and may be expected to have left their effects on the submerged Mediterranean border slopes. Such, indeed, is the case, as shown by the isobathic contours, but far less distinctly than in the case of the submerged borders of the Atlantic. In the first place, the great continental shelf of the Atlantic is in the case of the Mediterranean, narrow, and not well defined; and is represented generally by a broken slope, continuous with the bordering lands down to a depth of about 1,000–1,200 fathoms, when it gives place to the gradually shelving floor of the abyssal region, which descends to depths of over 1,500 fathoms. As a consequence of this, and as we might *a priori* expect, the submerged river-valleys are also less clearly defined than those off the coasts of France, Spain, and Portugal. Where, as in these cases, there exists a gently sloping terrace, extending for 100 to 200 miles out to sea, and traversed by deep channels with steep, sometimes precipitous, sides (as in the case of the Loire, the Adour, and the Tagus), it is easy to identify their courses by means of the soundings on the Admiralty charts; but where such channels only traverse for a short distance a steeply sloping surface, the conditions are entirely altered, and they are consequently less clearly recognizable. Notwithstanding this, however, the submerged channels of the Rhône and the Ebro can be clearly recognized by the inward bend of the contours opposite the mouths of these rivers, extending from about the 50 to the 1,000-fathom contours at the margin of the abyssal floor.

I may add, in conclusion, that I have succeeded in tracing Admiral Spratt's channel, between Adventure Bank and Cape Bon, by which the waters of the Levant Basin were connected with those of the Tyrrhenian Sea during the uplift of the entire area to the extent of 250 fathoms (1,500 feet), as explained by Admiral Spratt himself.[1]

EDWARD HULL.

OBITUARY.

DR. HENRY HICKS, F.R.S., F.G.S.

BORN IN 1837. DIED NOVEMBER 18, 1899.

THE mournful news has just reached us (November 21st) of the death of our genial friend and warm-hearted colleague, Dr. Henry Hicks. The son of the late Thomas Hicks, surgeon, of St. David's, Pembrokeshire, he was born in 1837, and was educated at the Collegiate and Chapter School in that city, and at Guy's Hospital, London. He became a member of the Royal College of Surgeons and a Licentiate of the Society of Apothecaries in 1862, and M.D. of the University of St. Andrew's in 1878, practising medicine at St. David's from 1862 to 1871. During that time he commenced his geological researches amongst the older rocks of that neighbourhood. His first paper was communicated to the Liverpool Geological Society in 1863. In the following year, in conjunction with the late Mr. J. W. Salter, Palæontologist to the Geological Survey,

[1] Q.J.G.S., vol. xxiii, p. 292.

he contributed several papers to the Geological Society, British Association, etc. In 1871 he removed to Hendon, Middlesex, and since that time he carried on researches in North Wales and Scotland, the results being communicated in numerous papers to the Geological Society, Geologists Association, and the GEOLOGICAL MAGAZINE. Of late his investigations were confined mainly to the oldest (Pre-Cambrian) rocks of Great Britain, and he has shown that they are exposed in many areas in which their presence had been hitherto unsuspected. Dr. Hicks described many new fossils discovered by him in the Cambrian, Ordovician, and Silurian rocks, and has written several papers on their classification. He published the results of explorations carried on by him in the ossiferous caverns in North and South Wales, in which evidence is given to show that man occupied some of the caverns during a part of the Glacial Period. In 1891 he described the glacial deposits at Hendon and Finchley, and in 1892 he published an account of the discovery of Mammoth and other remains in Endsleigh Street, London, with sections of the deposits in which they were found. He also wrote several papers on the rocks of North Devon, and discovered a rich fauna in the "Morte Slates," which until then were considered to be entirely unfossiliferous. In 1896–7 he published his views on the "Morte Slates" of North Devon and West Somerset in the GEOLOGICAL MAGAZINE. He prepared a new Geological Map of North Wales for the International Geological Congress which met in London in 1888. Dr. Hicks was awarded the Bigsby Medal by the Geological Society in 1883, and served that Society as Hon. Secretary and afterwards as President during the years 1896 and 1897. He was President of the Geologists Association in 1883–5, and was elected a Fellow of the Royal Society in 1885. He was an Honorary and Corresponding Member of many Geological and Natural History Societies in this country and abroad. Dr. Hicks died rather unexpectedly at his residence at Hendon, after only a very short illness, on November 18th, in his sixty-second year. His loss will be keenly felt by his many friends in the Geological Society and the Geologists Association, who appreciated his great abilities and sterling worth.

SIR J. WILLIAM DAWSON, C.M.G., LL.D. (EDIN.), D.C.L., F.R.S., F.G.S.

BORN OCTOBER 30, 1820. DIED NOVEMBER 19, 1899.

A TELEGRAM in the *Morning Post* of November 20th announces the death on the 19th inst., at the age of 79, of this eminent Canadian geologist, who was almost equally well-known and beloved among geologists on this side of the Atlantic.

Sir J. William Dawson was born at Pictou, Nova Scotia, on October 30th, 1820. He graduated at the University of Edinburgh, and returning home devoted himself to the study of the Natural History and Geology of Nova Scotia and New Brunswick. The results of these investigations were published in his "Acadian Geology" (3rd ed., 1878). In 1842, and again in 1852, he accompanied Sir Charles Lyell in his explorations in Nova Scotia,

aiding him materially in his investigations. Since 1843 he contributed largely to the Quarterly Journal of the Geological Society of London, the GEOLOGICAL MAGAZINE, and to other scientific periodicals. He has published numerous monographs on subjects connected with Geology, more especially on the Land Animals and Plants of the Palæozoic Period and on the Pliocene Deposits of Canada. His two volumes on the Devonian and Carboniferous Flora of "Eastern North America," published by the Geological Survey of Canada, are among the most important contributions yet made to the Palæozoic Botany of North America. He described *Eozoön Canadense* of the Laurentian limestones, at that time considered to be the earliest known form of animal life.

In 1850 he was appointed Superintendent of Education for Nova Scotia, and in 1855 Principal of M'Gill University, Montreal. He was a member of many learned Societies in Europe and America. Among his works are "The Story of the Earth and Man," 1872, in which he gives a popular summary of geological history; "The Dawn of Life," 1875, an account of the oldest known fossil remains, and of their relations to geological time and the development of the animal kingdom; "The Origin of the World," 1877; "Fossil Men and their Modern Representatives," 1878; and "The Chain of Life in Geological Time," 1880, a sketch of the origin and succession of animals and plants.

In 1882 he was awarded the Lyell Medal by the Geological Society of London in recognition of his original researches in the South Joggins Coalfield, Nova Scotia, and his other valuable contributions to geological knowledge. The same year he was created a Companion of the Order of St. Michael and St. George; and was selected by the Governor-General, the Marquis of Lorne, to be the first President of the Royal Society of Canada. He was also President of the American Association for the Advancement of Science. In the following year he attended the meeting of the British Association at Southport, and travelled in Egypt and Syria, on the geography and geology of which he published several papers. He was knighted by Her Majesty in 1884. In 1886 he served the office of President of the British Association for the Advancement of Science at Birmingham. In 1893 he was elected President of the American Geological Society. He retired from the office of Principal of M'Gill University July 31st, 1893, and was appointed Emeritus Principal, and Professor and Hon. Curator of the Peter Redpath Museum. Some of Sir W. Dawson's more recent works are "The Geological History of Plants," 1888; "Salient Points in the Science of the Earth," 1893; "The Canadian Ice Age," 1894; "The Meeting-place of Geology and History," 1894; "The Historical Deluge in its Relation to Scientific Discovery and to Present Questions," 1895; "Relics of Primeval Life," 1897.

Throughout his long and active career, Sir J. W. Dawson has contributed in a high degree to the advancement of geology and of science generally in Canada, and under his leadership the M'Gill University has risen to be the principal centre of scientific education and research in the Dominion.

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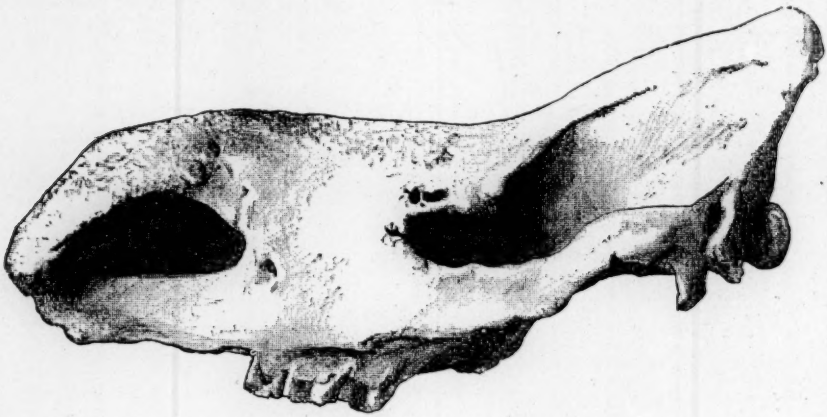

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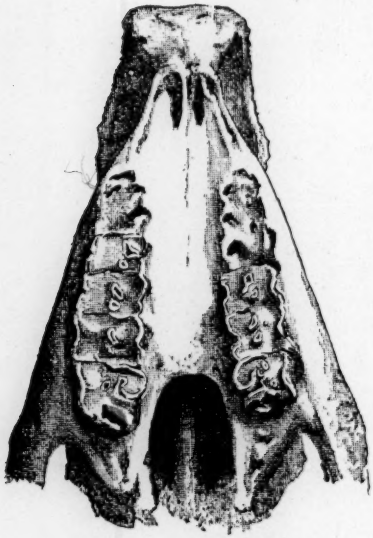

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